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THE LOOK BOX

STUDENTS of economics ignore the additional power in high-octane gasoline when they cite its cost as evidence that it can not become popular. It is true that gasoline of 91 or 100 octane costs more than the customary 72-octane product. Present difference between motor fuel of the common variety and cost of aviation grades makes it foolhardy to expect the motorist to pay such a difference, provided he thus buys no more power.

Cost and Power

But the higher the octane rating the more work gasoline will do. When more power plays counter to higher price the difference in cost diminishes.

Over a decade, however, the motorist has dissipated this added power in better gasoline by accepting a heavier automobile. He has given away his saving in power by being willing to get away from the signal light first. Whenever he is willing to continue driving at his former speed, he can have the saving in better gasoline by traveling more miles on a gallon.

SCIENCE should not seek the advantage of edicts. Instead of asking that prices for raw materials be raised, it should produce methods whereby extra value accrues to a raw material. The more useful finished products become, the higher the price of raw sources will rise. Thus the man who can perfect the better processes is in position to increase the price of the materials for his processing.

Not By Edict

The short cut of seeking a higher price through government in order that raw materials be diverted to better use, is dangerous on another count. New processes thrive on cheap raw materials. Especially in the early years of a new industry, cheap raw material is advantageous.

A higher price for a raw material could hamper scientific development rather than help it.

The student of any industry will find numerous instances of what seems to be improper use of raw material. That it follows these channels partly because of low cost is admitted. An arbitrary price increase no doubt will halt improper uses. But the higher price will not encourage other uses.

Science has its opportunity in providing the methods whereby these low-cost materials can be converted into such useful finished materials that demand will alter the price at the source.

THERE is a popular impression that every soldier wants a Jeep for peacetime use. The popularity of this member of the military automotive family reaches into civilian life. Evidently its future will be something more than a novelty. In the opinion of Ward M. Canadday, Willis Overland Motors, it promises to influence the consumption of motor fuel because of its popularity and adaptibility. Over a radio hookup he said:

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begins where the paved road ends. The peace Jeep adapted for peace work as the war Jeep was adapted for its job will solve the farmer's scarce manpower problem; it seems to be the practical solution for the rural power and utility transportation. It will dig wells, saw wood, fill silos, run electric light plants, supply mobile power for all farm requirement, act as a tractor, then as a truck, then as a transport car—hauling people, hauling milk and produce, operating logging camps, herding cattle, fighting fires, running a snow plow, spraying orchards, spray-painting barns, operating compressor equipment for mining operations, road building, railroad building.

"There seems to be no limits to the suggestions of its practicability. Fundamentally, it looks as if it will become the tireless utility vehicle wherever work is done."

Give And Take

ALONG with some jealousies that have arisen as alcohol and petroleum have vied for their places in providing chemical rubber ingredients, it is heartening to note how the two are bolstering each other in the large war effort. These observations are from a report made public in February concerning the combination butadiene and styrene plant at Kobuta, Pennsylvania, operated by Koppers Company.

Along with its styrene production the plant is recovering around 50,000 gallons of toluene each month. This goes into aviation gasoline as well as into TNT. This plant also recovers secondary butylbenzene, which goes to refining plants for blending into aviation gasoline. A polythylbenzee recovery is being sent to plants where the alkylation process is used for production of ethylbenzene. Between June and November, 1944, the Kobuta plant produced 16,000,000 pounds of ethylbenzene for use in aviation gasoline.

Ethyl (grain) alcohol is the raw material at Kobuta, where 40,000 gallons are charged daily.

It is singular that the refining industry in its several chemical processing plants makes more ethyl alcohol that is used at Kobuta.

Things Not Jobs

IN CENTERING attention on the accomplishment of 60,000,000 jobs as a postwar goal the thought of the nation is poorly applied. It is goods and services that human beings need and want. Jobs are secondary to filling needs and wants.

A job program may be created by decree. Thus 60,000,000 men and women may be put to work. In such a program they can make useful things or nonuseful things and the jobs still will exist. Thus a job program could continue until storage space ceased to exist.

The American Federation of Labor has corrected this viewpoint. It proposes to build 19,000,000 homes. The nation may need even more homes the the A. F. of L. estimates.

Regardless of the need, the point to remember is that this nation and its workers will be better served when there is a determination to provide the goods and services a people need rather than a determination to provide 60,000,000 jobs.

Oil can provide many more jobs than it ever has known simply by expanding the use of its products into fields other than fuel and lubricants. Whatever it does for plastics, for chemical rubber, for fertilizers, for medicine, will establish more jobs simply by providing what men and women need.

An expanding economy is the real need. In it the number of jobs will match the extent of more goods and services.

Engines and Their Fuels

IN THE opinion of T. B. Bendel, Shell Oil Company, high-speed diesel engines offer no immediate promise of supplanting the gasoline engine in automobiles and light airplanes. In his paper before the Metropolitan Section, SAE, he said:

"While we may expect an effort to increase the speed and therefore the power output of the light diesel engine, it is hardly probable that the overall economy, taking into account the increased weight, will enable it to compete with the gasoline engine. In addition to this, from the private owner's point of view, there is the very practical objection that diesel fuel does not evaporate clean, and the problem of cleanliness of personally-owned diesel equipment will loom very large."

Of other fuels he added:

"It is not probable that in the near future internal-combustion engines will be able to consume solid fuels in powdered form and the manufacture of liquid fuels from coal is at present too expensive. Alcohol made from farm products is not at the present attractive as a fuel, since it can not be used at anything like the cost of petroleum fuels."

When the few British fliers (to whom so many owe so much shot down hundreds of German planes in the Battle of Britain, they had 100-octane gasoline in their Spitfires, giving them that vital extra margin of speed and altitude over German fliers using inferior fuel. Ten to thirteen octane numbers may well have shaped the history of the world in that battle!

—ROBERT E. WILSON, *Chairman, Standard Oil Company (Indiana).*

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New Method for Equilibrium Vaporization Calculation

EARL E. McREYNOLDS
Process Engineer, J. S. Abercrombie Company and Harrison Oil Company

THE method presented herein is a time- and labor-saving device for calculations involving equilibrium vaporization of mixtures for which the "K" values of the components are known. This new method eliminates trial and error, and from one to three calculations for each component and summations.

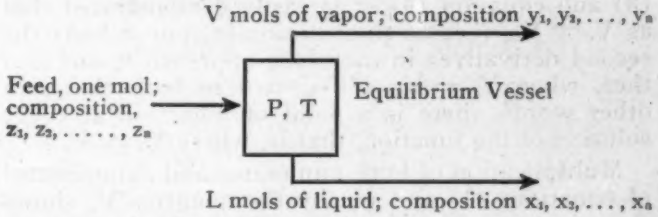
The method involves successive approximations, each one of which is closer to the correct value than the preceeding one. The first is an estimate, and the following approximations are calculated from the first mathematically. In this manner, the solution can be carried to any desired degree of precision. Furthermore, the mathematical nature of the functions involved is such that two or three approximations including the first estimate, are usually sufficient to obtain an answer well within the limit of precision of the "K" values for petroleum hydrocarbons.

The fundamental equations used are the same as in the time-honored trial-and-error method of calculation. The deviations of these and the supplemental equations necessary for the new method are presented both for their mathematical interest and to demonstrate the limitations of the new method. After each derivation and discussion, a summary and examples are given to clarify the presentation and to illustrate the applications. A table of nomenclature and a complete summary and tabulation of the necessary equations for problem solution, follow at the end of the article, and make up a convenient reference for use in solving vaporization problems.

Nomenclature

f' and f" refer respectively to the first and second derivatives.
K is the vaporization equilibrium constant, y/x.
K_R is the equilibrium constant for the reference component.
L is the number of mols of liquid per mol of feed.
L_a is the number of mols of liquid when $V = V_a$.
R is a subscript referring to the reference component.
V is the number of mols of vapor per mol of feed, or the mol % vapor.
V_a is the assumed value of V.
V_c is the value of V calculated by assuming V_a.
x is the mol fraction of component in the liquid.
y is the mol fraction of component in the vapor.
z is the mol fraction of component in the feed.
(n>1) refers to a number greater than one.

Derivation of Equations


V mols of vapor; composition $y_1, y_2, \ldots, y_n$
Feed, one mol; composition, $z_1, z_2, \ldots, z_n$
P, T
Equilibrium Vessel
L mols of liquid; composition $x_1, x_2, \ldots, x_n$

By material balance, $V + L = 1$.
By definition of K, $K_n = y_n/x_n$, or in general, $K = y/x$.
For any component,

$$(a)\ z = yV + xL = VKx + xL = x(VK + L)$$
$$(b)\ z = yV + yL/K = y(V + L/K)$$

$$(a)\ x = \frac{z}{VK + L} \qquad (b)\ y = \frac{zK}{VK + L}$$

$$Vx = \frac{z}{K + L/V} \qquad Vy = \frac{zK}{K + L/V}$$

Since $\Sigma x = 1$, Since $\Sigma y = 1$,

$$(a)\ V = \Sigma\frac{z}{K + L/V} \qquad (b)\ V = \Sigma\frac{zK}{K + L/V}$$

These (equations a and b) are the fundamental equations used for calculating the percent vaporized at a given temperature and pressure for a mixture. In the usual method, a value of V is assumed, and the $\frac{z}{K + L/V}$ or $\frac{zK}{K + L/V}$ for each component is summed up. The assumptions and summations are continued until the summation equals the assumed value of V. The assumed values may be plotted against the calculated values to guide later assumptions, but due to an inherent slow convergence to a solution which is often met, the graphical answer usually must be checked, and then even adjusted again and checked by a final trial.

The new method proposes to eliminate this trial-and-error feature of equilibrium vaporization problems.

Mathematical investigation of the trial-and-error

method leads quite naturally to the new method:

Method A

Given: Temperature, pressure, composition.
Find: Percent vapor.
Let V_c be the calculated value of V when assuming a value V_a. Then, for equation (a),

$$\text{Eq. (1)} \quad V_c = f(V_a) = \sum \frac{z}{K + L_a/V_a}$$

If $\phi(V) = L/V = \frac{1-V}{V}$, then $\phi'(V) = -1/V^2$. Hence,

$$\text{Eq. (2)} \quad f'(V_a) = (1/V_a^2) \sum \frac{z}{(K + L_a/V_a)^2}$$

$$\text{Eq. (3)} \quad f''(V_a) = (2/V_a^3) \sum \frac{z - zK}{(K + L_a/V_a)^3}$$

Similarly, for equation (b) above, we have,

$$\text{Eq. (4)} \quad V_c = f(V_a) = \sum \frac{zK}{K + L_a/V_a}$$

$$\text{Eq. (5)} \quad f'(V_a) = (1/V_a^2) \sum \frac{zK}{(K + L_a/V_a)^2}$$

$$\text{Eq. (6)} \quad f''(V_a) = (2/V_a^3) \sum \frac{K(z - zK)}{(K + L_a/V_a)^3}$$

Since the factor $\frac{z - zK}{K + L_a/V_a}$ appears in both equation (3) and equation (6), it is easily demonstrated that as $V_c \to V_a$, (i.e., as the solution is approached) the second derivatives in each case approach 0, and further, when $V_c = V_a$, $f''(V_a) = 0$ in both cases. In other words, there is a point of inflection at every solution of the function, that is, where $V_c = V_a$.

Multiplication of both numerator and denominator of equations (1) and (4) by the quantity V_a shows that, for any correct value of V, as V_a becomes 0, $f(V_a)$ also becomes 0.

For equation (1), as $V_a \to 1$, $f(V_a) \to \Sigma z/K$, at any correct value of V. As, at the same time, the correct V becomes 1, $\Sigma z/K$ also becomes 1. At any correct value of V less than 1, $\Sigma z/K$ is greater than 1, since the K values are less than those corresponding to the dew point, where $\Sigma z/K = 1$. In other words, as $V_a \to 1$, $f(V_a) \to (n>1)$.

However, in equation (4), as $V_a \to 1$, $f(V_a) \to \Sigma z = 1$ for any correct value of V.

For equation (2), as $V_a \to 0$, $f'(V_a) \to \Sigma z = 1$, for any correct V. For equation (5) however, as $V_a \to 0$, $f'(V_a) \to \Sigma zK$. Since the $\Sigma zK = 1$ only at the bubble point, at any correct value of V greater than 0, as $V_a \to 0$, $f'(V_a) \to (n>1)$.

As $V_a \to 1$, equation (2) gives $f'(V_a) \to \Sigma z/K^2$. Since, at any correct value of V less than 1, the K values are too small for $\Sigma z/K = 1$, it follows that $\Sigma z/K^2 > \Sigma z/K > 1$. Therefore, as $V_a \to 1$, $f'(V_a) \to (n>1)$. Equation (5) gives the same net result as $V_a \to 1$, except that $f'(V_a) \to \Sigma z/K$, which is greater than one except at the dew point.

Since both equation (3) and equation (6) contain the factor $(z - zK)$ in the value of the function as $V_a \to 0$, and since $\Sigma z = 1$ and $\Sigma zK > 1$, $f'(V_a)$ is negative in both cases as $V_a \to 0$.

As $V_a \to 1$, we find that equation (3) shows $f''(V_a) \to 2\,\Sigma z/K^2 - z/K^2$, and that equation (6) gives $f''(V_a) \to 2\,\Sigma z/K^2 - z/K$. Since the K values are too small for $\Sigma z/K = 1$ at any correct value of V less than 1, and this proves that $\Sigma z/K^3 > \Sigma z/K^2 > \Sigma z/K > 1$, then it follows that $f''(V_a)$ is positive as $V_a \to 1$.

Summarizing the above discussion, we have:

Set I

Equation (1); as $V_a \to 0$, $f(V_a) \to 0$.
Equation (2); as $V_a \to 0$, $f'(V_a) \to 1$.
Equation (3); as $V_a \to 0$, $f''(V_a)$ is $-$.
Equation (1); as $V_a \to 1$, $f(V_a) \to (n>1)$.
Equation (2); as $V_a \to 1$, $f'(V_a) \to (n'>n>1)$.
Equation (3); as $V_a \to 1$, $f''(V_a)$ is $+$.
Equation (3); as $V_c \to V_a$, $f''(V_a) \to 0$.

Set II

Equation (4); as $V_a \to 0$, $f(V_a) \to 0$.
Equation (5); as $V_a \to 0$, $f'(V_a) \to (n>1)$.
Equation (6); as $V_a \to 0$, $f''(V_a)$ is $-$.
Equation (4); as $V_a \to 1$, $f(V_a) \to 1$.
Equation (5); as $V_a \to 1$, $f'(V_a) \to (n>1)$.
Equation (6); as $V_a \to 1$, $f''(V_a)$ is $+$.
Equation (6); as $V_c \to V_a$, $f''(V_a) \to 0$.

Figure I shows the general shape of the curves from the function defined by equation (1) for cases in which the solution is near one, and for solutions near 0. Figure II shows the same for the function defined by equation (4), and both figures diagrammatically show the derivation of equation (7), which is used for calculating the assumptions following the first estimate.

Figure IIIa illustrates the behavior of both Set I and Set II for $V>0.5$, and Figure IIIb illusrates both sets for $V<0.5$. These curves were carefully plotted from an actual case (see example 1). Inspection of Figures IIIa and IIIb shows that the points of inflection at the solutions are of little significance in this case, except in the vicinity of $V = 0$, and $V = 1$. The second derivative does not change sign as the curve passes through the practical solution; it merely reaches the value 0 and takes the same sign on the other side of the solution. Furthermore, other inflection points exist, which are determined by the values of the z's and K's for the individual components rather than the value of V_a. For this reason, a concise mathematical analysis of the functions at all points between $V_a = 0$ and $V_a = 1$ is quite difficult to make, but enough for practical application of the method is quite apparent. The second derivatives do determine the direction of approach to the solution, and since from physical considerations there is only one practical solution of a given function, the general

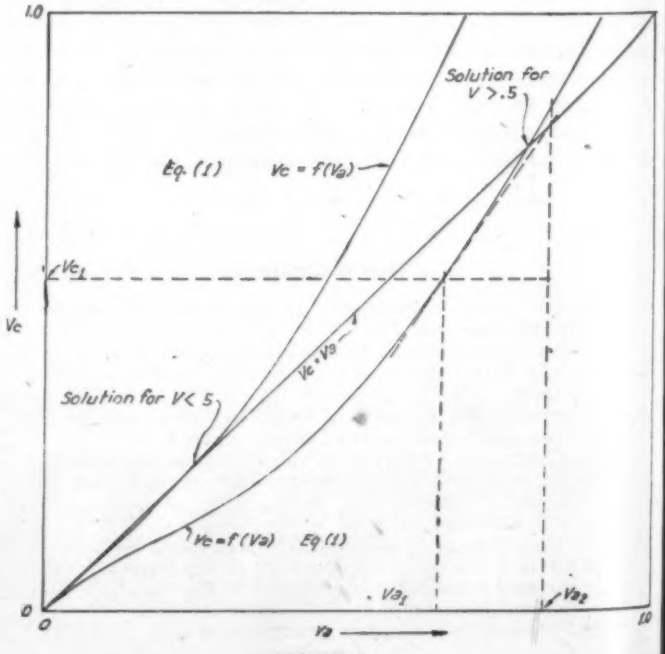


FIGURE I

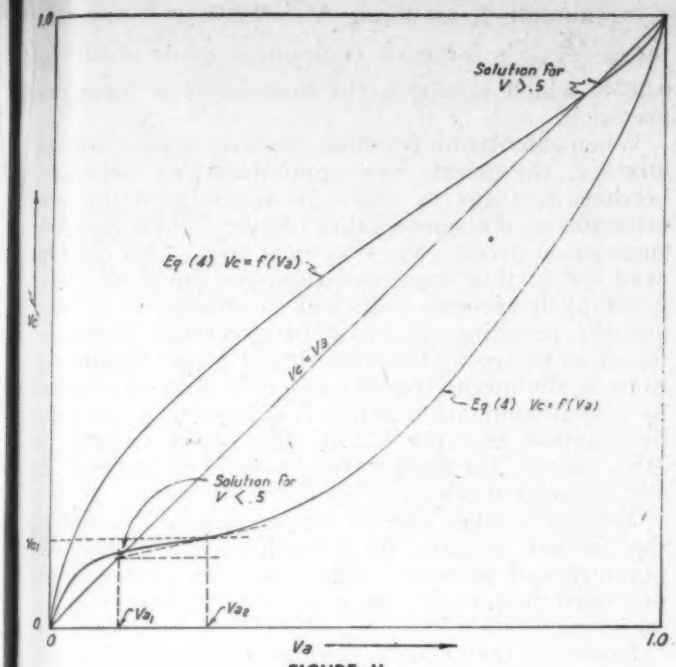


FIGURE II

shape of the curves must be as shown in Figures I and II.

From Figure I, $f'(V_{a1}) = \frac{V_{a2} - V_{c1}}{V_{a2} - V_{a1}}$; whence we obtain,

Equation (7) $V_{a2} = \frac{V_{a1}f'(V_{a1}) - V_{c1}}{f'(V_{a1}) - 1}$

Thus, we can continue to calculate successive approximations by evaluating $f(V_{a2})$ and $f'(V_{a2})$ from which we can calculate V_{a3} etc. to any desired degree of precision.

From Figure II, $f'(V_{a1}) = \frac{V_{c1} - V_{a2}}{V_{a1} - V_{a2}}$; and from this,

Equation (7) $V_{a2} = \frac{V_{a1}f'(V_{a1}) - V_{c1}}{f'(V_{a1}) - 1}$

It should be noted here that this method of obtaining successive approximations to the solution of an equation is an adaptation of Newton's method for the solution of equations.

From Figures I, II, and III, it is apparent that the function defined by equation (1) should be used for values of V near 1, and that equation (4) should be used when V is near 0. The rapidity of convergence to a solution is usually much greater for the above rule than for the converse, and this is still nearer true the nearer V is to 1 or 0. A good rule to follow is to use equation (1) for cases in which V is greater than 0.5 and to use equation (4) for cases in which V is less than 0.5, remembering that either function may be used in the vicinity of 0.5. However, there do exist cases (see example 2) in which, due to unusual z and K values, the slope of the function in equation (4) in the vicinity of a solution less than 0.5 is nearer one than is the slope of equation (1). When this is the case, it is apparent by the value of $f'(V_{a1})$ being near 1 (say above 0.95). When such a case as this is met, it is well to make a rough free-hand drawing of the curves to determine which function will give the more quickly converging solution.

In example 2, the solution was reached easily in two summations and a calculated third approximation, but cases do exist in which the effect mentioned in the above paragraph is more exaggerated than in example 2, and in which a faster solution could be obtained by changing functions.

Calculation Procedure for Method A

Given: Temperature, pressure, composition.
Find: Percent vapor.
Case I, V is greater than 0.5; use Set I (equations 1, 2, and 7). Assume V_{a1}, calculate the resulting L/V, and tabulate as follows:

Component	z	K	K + L/V	$\frac{z}{K+L/V}$	$\frac{z}{(K+L/V)^2}$

Since, by any method, the quantity $\frac{z}{K+L/V}$ for each component is in the slide rule, it is very little

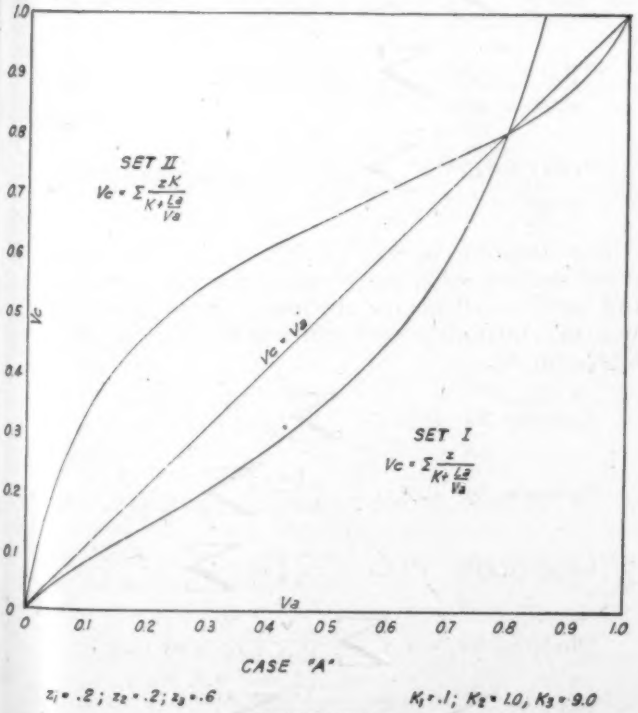


FIGURE IIIA

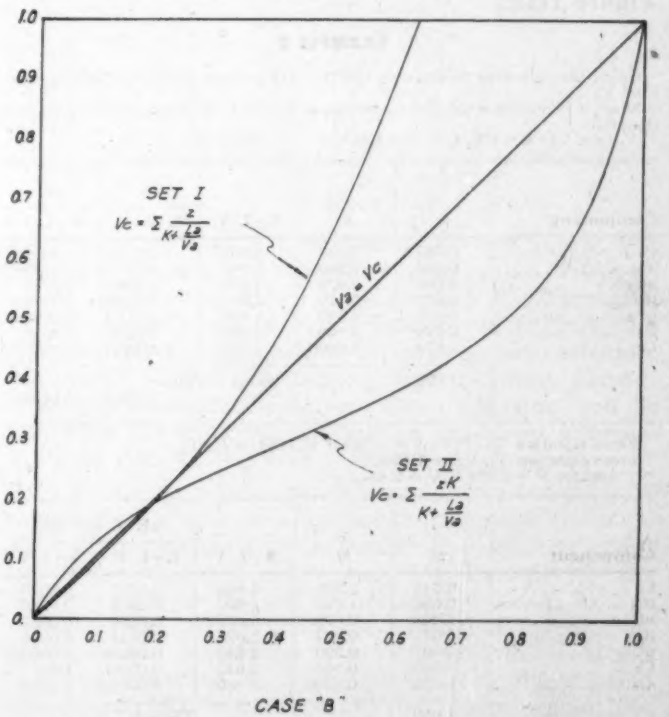


FIGURE IIIB

trouble to simply divide again by $K + L/V$ to obtain $\frac{z}{(K+L/V)^2}$. Having obtained V_{c_1} from equation (1) and $f'(V_{a_1})$ from equation (2), substitute in equation (7) to find V_{a_2} and repeat the process. The third approximation is usually sufficient.

For Case II (where V is less than 0.5) the same procedure is followed except that Set II (equations 4, 5 and 7) are used, and the corresponding tabulations are made.

Obviously, from Figures I, II, and III, too great an error in the first assumption of V_{a_1} will give a second approximation, V_{a_2}, which is more in error than the first. However, in actual practice, it is usually possible to estimate a reasonable V_{a_1}, and if not, the resulting V_{a_2} is so absurd that the error is detected by a single summation.

EXAMPLE 1
(See Figure IIIa)

Given: T. P. (and therefore K for each component). Find: V.
Since V is greater than 0.5, use equations 1, 2, and 7.
Assume $V_{a_1} = 0.9$; $L/V = 0.111$.

Component	z	K	K+L/V	$\frac{z}{K+L/V}$	$\frac{z}{(K+L/V)^2}$
1	0.2	0.1	0.211	0.947	4.490
2	0.2	1.0	1.111	0.180	0.162
3	0.6	9.0	9.111	0.066	0.007
	1.0	..	....	$V_{c_1} = 1.193$	4.659

From equation (2) $f'(V_{a_1}) = (1/0.9)^2 (4.659) = 5.75$. From equations (7), $V_{a_2} = 0.840$.
Assume $V_{a_2} = 0.840$; $L/V = 0.190$.

Component	z	K	K+L/V	$\frac{z}{K+L/V}$	$\frac{z}{(K+L/V)^2}$
1	0.2	0.1	0.290	0.690	2.380
2	0.2	1.0	1.190	0.168	0.141
3	0.6	9.0	9.190	0.065	0.007
	1.0	..	....	$V_{c_2} = 0.923$	2.528

From equation (2) $f'(V_{a_2}) = 3.585$. From equation (7) $V_{a_3} = 0.805$.

For most purposes, this is sufficiently close. (See Figure IIIa.)

EXAMPLE 2

Given the following mixture at 158° F., 110 pounds per square inch gauge. Find V.
Since V is less than 0.5, use equations 4, 5, and 7. (V is estimated to be less than 0.5).
Assume $V_{a_1} = 0.400$; $L/V = 1.500$.

Component	z	K	K+L/V	$\frac{zK}{K+L/V}$	$\frac{zK}{(K+L/V)^2}$
C_3	0.045	2.390	3.890	0.0276	0.0071
iC_4	0.686	1.240	2.740	0.3105	0.1133
nC_4	0.068	0.976	2.476	0.0268	0.0108
iC_5	0.071	0.470	1.970	0.0169	0.0086
nC_5	0.007	0.390	1.890	0.0014	0.0008
C_6	0.049	0.160	1.660	0.0047	0.0028
C_8	0.074	0.0296	1.530	0.0014	0.0009
	1.000	.....	.....	$V_{c_1} = 0.3893$	0.1443

From equation (5), $f'(V_{a_1}) = (1/0.4)^2 (0.1443) = 0.902$.
From equation (7), $V_{a_2} = 0.293$.
Assume $V = 0.29$; $L/V = 2.45$.

Component	z	K	K+L/V	$\frac{zK}{K+L/V}$	$\frac{zK}{(K+L/V)^2}$
C_3	0.045	2.390	4.840	0.0222	0.0046
iC_4	0.686	1.240	3.690	0.2305	0.0625
nC_4	0.068	0.976	3.426	0.0194	0.0057
iC_5	0.071	0.470	2.920	0.0114	0.0039
nC_5	0.007	0.390	2.840	0.00096	0.0003
C_6	0.049	0.160	2.610	0.0030	0.0011
C_8	0.074	0.0296	2.480	0.00088	0.0004
	1.000	.....	.....	$V_{c_2} = 0.2883$	0.0785

From equation (5), $f'(V_{a_2}) = (1/0.29)^2 (0.0785) = 0.934$.
From equations (7), $V_{a_3} = 0.266$ which is near enough.

In example 2, assuming $V = 0.266$ and summing the $\frac{zK}{K+L/V}$'s for each component gives a sum of 0.2658, which is within the limitations of slide-rule precision.

When calculating complete flash curves for a given mixture, the number of approximations necessary becomes less due to a gain in accuracy of the first estimate as the curve takes shape. When the first summation gives a V_{c_1} very near to V_{a_1}, there is no need for further approximation. As the flash curve develops, it becomes sufficient to estimate a V_{a_1} and use the resulting V_{a_2} without checking. However, this does not mean that one should forget the limitations of the method; and answers should be checked by a final summation unless it is known by previous information that the V_a in question is correct. In other words, the final answer should in general, be a V_c instead of a V_a.

Method A takes care of the problem of calculating the percent of vapor for a mixture at a given temperature and pressure. This type of problem is the one most frequently met with in vaporization problems.

However, the problem frequently arises which presents a slightly different angle. For the purpose of calculating the temperature (or pressure) at which a given percentage of a mixture is vaporized at a given pressure (or temperature), Method B is developed below.

Method B

The problem dealt with in Method B is to find the temperature (or pressure) at which a given percent of a given mixture is vaporized at a given pressure (or temperature). V, and therefore L/V, are given.

For any component, n, let $\alpha_n = K_n/K_R$, or in general, $\alpha = K/K_R$ where K_R is K for one of the components chosen as the reference component. α for petroleum hydrocarbons is relatively constant over moderate ranges of temperature.

Let $f(K_R) = \sum \frac{zK}{K+L/V} = \sum \frac{z\alpha K_R}{\alpha K_R + L/V}$. Then,

$$f'(K_R) = \sum \left(\frac{-zK_R\alpha^2}{(\alpha K_R + L/V)^2} + \frac{zK_R\alpha^2 + z\alpha(L/V)}{(\alpha K_R + L/V)^2} \right), \text{ or}$$

$$f'(K_R) = (L/V) \sum \frac{z\alpha}{(\alpha K_R + L/V)^2}, \text{ which is always positive, and}$$

$$f''(K_R) = (L/V) \sum \frac{-2z\alpha^2}{(\alpha K_R + L/V)^3}, \text{ which is always negative.}$$

The solution occurs at $f(K_R) = V$. In order to avoid dealing with the α values for each component, and also to eliminate the error introduced by the lack of constancy of α, substitute K for αK_R and K/K_R for α.

Equation (8) $f(K_R) = \sum \frac{zK}{K+L/V}$

Equation (9) $f'(K_R) = \frac{L}{VK_R} \sum \frac{zK}{(K+L/V)^2}$

Equation (10) $f''(K_R) = \frac{-2L}{VK_R^2} \sum \frac{zK^2}{(K+L/V)^3}$

Similarly, for $V = \sum \frac{z}{K+L/V}$, we may let

$f(K_R) = \sum \frac{z}{K+L/V} = \sum \frac{z}{\alpha K_R + L/V}$. Then,

$f'(K_R) = \sum \frac{-z\alpha}{(\alpha K_R + L/V)^2}$ which is always negative, and

$f''(K_R) = \sum \frac{2z\alpha^2}{(\alpha K_R + L/V)^3}$ which is always positive.

Substituting K/K_R for α and K for αK_R, we have

Equation (11) $f(K_R) = \sum \frac{z}{K + L/V}$

Equation (12) $f'(K_R) = -1/K_R \sum \frac{zK}{(K + L/V)^2}$

Equation (13) $f''(K_R) = 2/K_R^2 \sum \frac{zK^2}{(K + L/V)^3}$

The solution occurs at $f(K_R) = V$. When V is small, L/V is large, and $f'(K_R)$ is greater for equation (9) than for equation (12). Therefore, the solution is more rapidly convergent for equation (8) than for equation (11). Hence, equations 8 and 9 should be used when V is less than 0.5.

When V is large, L/V is small, and $f'(K_R)$ is greater for equation (12) than for equation (9). Obviously, the greater the slope at the solution, the clearer the solution, so equation (11) is more quickly convergent than equation (8). Hence, equations 11 and 12 should be used when V is greater than 0.5.

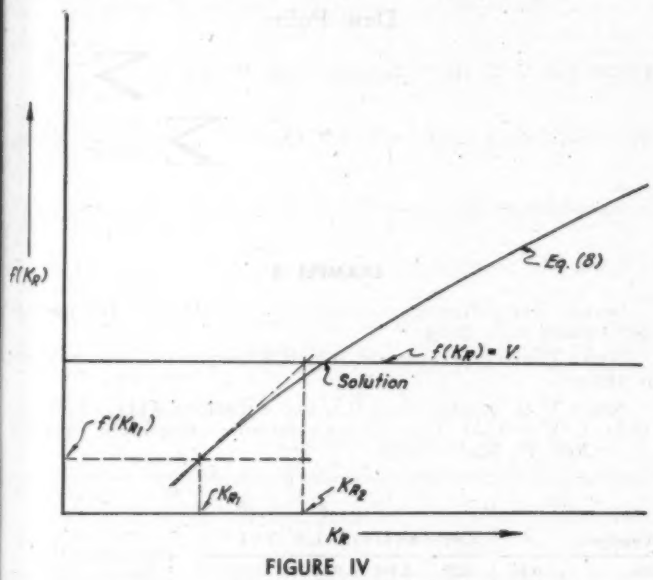


FIGURE IV

Figures IV and V are obviously the general curves for equations 8 and 11 respectively. For equation (8), the slope is always + and always decreasing (Figure IV) and for equation (11), the slope is always — and always increasing (Figure V). Both figures also show the derivation of equation (14).

From either Figure IV or Figure V, $f'(K_{R1}) = \frac{V - f(K_{R1})}{K_{R2} - K_{R1}}$ or

Equation (14) $K_{R2} = \frac{V - f(K_{R1})}{f'(K_{R1})} + K_{R1}$.

Calculation Procedure for Method B

Use the following procedure for calculating the temperature at a given pressure and percent vapor, or for calculating the pressure at a given temperature and percent vapor:

(1) Calculate L/V from the given V.

(2) Assume the temperature (or pressure) to be calculated, and therefore the K values for the components.

(3) Choose the reference component R which appears in appreciable quantities in both liquid and vapor. If V is less than 0.5, choose K_R for the component which has an appreciable x and y, but preferably a substantial y value. If V is greater than 0.5, choose K_R for the component which has both an appreciable x and y, but preferably a substantial x value. The nearer the mixture is to the dew point, the more important it is to choose K_R for a component with a substantial x value.

(4) Tabulate as follows:

Component	z	K	K + L/V	z or zK / K + L/V	zK / (K + L/V)²

(5) Using eq. (8) or eq. (11) as the case may be, calculate $f(K_{R1})$.

(6) Using eq. (9) or eq. (12) as the case may be, calculate $f'(K_{R1})$ for the K_{R1} chosen as in step (3) above.

(7) Calculate K_{R2} from eq. (14); $K_{R2} = \frac{V - f(K_{R1})}{f'(K_{R1})} + K_{R1}$.

(8) Repeat the process using the temperature obtained from the value calculated for K_{R2}. Using the new K's for each component at the new temperature, eliminates the error which was introduced in the derivation of the equations by the assumption that α is a constant. Two summations and a third calculated value of K_R are usually sufficient. The test for solution is, of course, $f(K_R) = V$.

For problems in which there is a choice of unknowns (percent vapor or temperature), method B is superior to method A because of a more rapid convergence to a solution, and because of the fact that the shape of the curves derived from equations (8) and (11) eliminates the possibility of the second

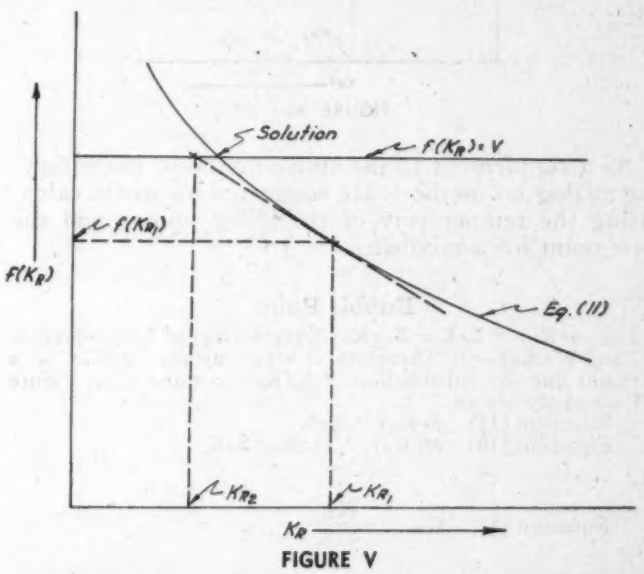


FIGURE V

approximation being worse than the first if the first approximation is less than the correct value. Furthermore, experience shows that no matter which side of the correct solution the first estimate falls on, the second approximation is nearer the solution. Naturally, if this is true for a first estimate greater than the solution, the second approximation will be less than the solution, and all the following approximations will be also less than the solution.

It should be added that if very precise calculations are desired, a plot of K versus temperature (or pressure, if pressure is the unknown) should be made for each component. Of course, this is simply for the sake of consistency of the K values used, and is necessary for precision in any method of calculation, and does not constitute a limitation of this method.

When choosing K_R, it should be remembered that when near the bubble point, the critical quantities are the y values of the components. Intuitively, this can be realized when it is considered that at the bubble point, the expressions involved reduce to a

summation of the y values, which is the means of calculating the bubble point. Conversely, near the dew point, it is the x values which are "critical." Therefore, it may be stated that it is better in general, to use as the reference component that one which appears in appreciable concentration in the phase whose concentration is most nearly being summed for the calculation, and which at the same time has a noticeable concentration in the less important phase.

This means that when near the bubble point, an intermediately light component is selected, and when near the dew point, an intermediately heavy component is selected as the reference component. The proper selection of the reference component sometimes markedly alters the rapidity of convergence to a solution for a given function.

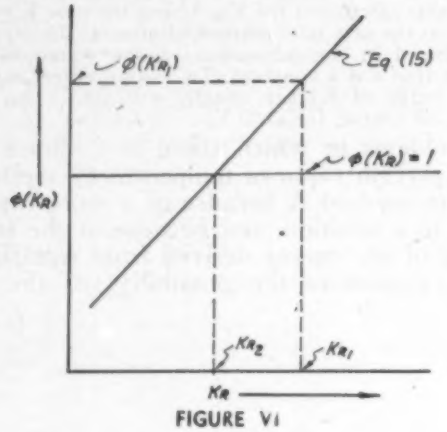


FIGURE VI

As a supplement to the above methods, the following analogous methods are suggested for use in calculating the temperature of the bubble point and the dew point for a mixture.

Bubble Point

Let $\phi(K_R) = \Sigma zK = \Sigma z\alpha K_R$. Then, $\phi'(K_R) = \Sigma z\alpha$, which is +, and $\phi''(K_R) = 0$. Therefore, if α is constant, $\phi(K_R)$ is a straight line. By substitution of K/K_R for α and from Figure VI we easily obtain,

Equation (15) $\phi(K_R) = \Sigma zK$

Equation (16) $\phi'(K_R) = (1/K_R)\,\Sigma zK$

Equation (17) $K_{R2} = \dfrac{K_{R1}}{\Sigma zK}$

EXAMPLE 3

Given: The following mixture at a pressure of 110 pounds per square inch, gauge.

Find: The temperature at which 20 percent is vaporized.

Since V is less than 0.5, use equations (8), (9), and (14). L/V = 0.8/0.2 = 4.0.

Assume temperature of 140° F. for first assumption. Use iC_4 for reference component. $K_{R1} = 1.040$.

Component	z	K140	K+L/V	zK K+L/V	zK (K+L/V)²	K156	K+L/V	zK K+L/V
C_3	0.045	2.080	6.080	0.0154	0.00253	2.350	6.350	0.0167
(R) iC_4	0.686	1.040	5.040	0.1418	0.02813	1.212	5.212	0.1598
nC_4	0.068	0.810	4.810	0.0115	0.00238	0.953	4.953	0.0131
iC_5	0.071	0.368	4.368	0.0060	0.00137	0.460	4.460	0.0073
nC_5	0.007	0.300	4.300	0.0005	0.00011	0.377	4.377	0.0006
C_6	0.049	0.120	4.120	0.0014	0.00035	0.155	4.155	0.0018
C_8	0.074	0.019	4.019	0.0003	0.00009	0.0282	4.028	0.0005
From equation (8), $f(K_{R1}) = 0.1769$					0.03496	From eq. (8), $f(K_{R2}) = 0.1998$		

From equation (9), $f'(K_{R1}) = (4/1.04)\,(0.03496) = 0.1345$.

From equation (14), $K_{R2} = \dfrac{0.2 - 0.1769}{0.1345} + 1.040 = 1.212$

$T_2 = 156°$ F., from the K chart. K at 156° for the other components are read off the K chart and not calculated by $K = \alpha K_R$. Thus α is eliminated. Since $f(K_{R2}) = 0.1998$ which is practically 0.200, there is no need for further approximation, and the desired temperature is 156° F.

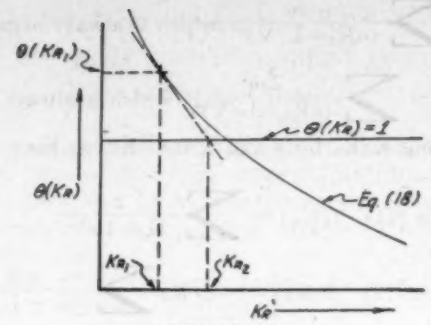


FIGURE VII

It should be noted again that the α values of each component must be constant over the temperature range from K_{R1} to K_{R2} if equation (15) is to be a straight line. This is not a badly wrong assumption in general, and since it is checked at the temperature corresponding to K_{R2}, thus eliminating the assumption from the answer, it is seldom necessary to do more than make a reasonable estimate of the bubble point, calculate the second approximation, and check with a second summation.

Following the same procedure used previously, this method involves the following tabulation:

Component	z	K	zK

Dew Point

Let $\theta(K_R) = \Sigma z/K = \Sigma z/\alpha K_R$. Then, $\theta'(K_R) = \sum \dfrac{-z\alpha}{\alpha K_R^2}$, which is always negative, and $\theta''(K_R) = \sum \dfrac{2z\alpha^2}{(\alpha K_R)^3}$, which

EXAMPLE 4

Given: The following mixture at a pressure of 170 pounds per square inch, gauge.

Find: The temperature at which 90 percent of the mixture is vapor.

Since V is greater than 0.5, use equations (11), (12), and (14). L/V = 0.111. Use iC_5 for reference component. Assume $T_1 = 260°$ F., $K_{R1} = 0.920$.

Component	z	K260°	K+L/V	z K+L/V	zK (K+L/V)²	
C_3	0.10	3.37	3.481	0.0287	0.0278	From equation (12), $f'(K_{R1}) = -0.7595$. From equation (14), $K_{R2} = 0.754$, and from the K chart, $T_2 = 233°$ F.
iC_4	0.22	1.97	2.081	0.1057	0.1000	
nC_4	0.10	1.61	1.721	0.0581	0.0543	
iC_5	0.40	0.92	1.031	0.3880	0.3460	
nC_5	0.18	0.82	0.931	0.1933	0.1703	
From equation (11), $f(K_{R1}) = -0.7738$					0.6984	

Component	z	K233°	K+L/V	z K+L/V	zK (K+L/V)²	
C_3	0.10	2.87	2.981	0.0335	0.0323	From equation (12), $f'(K_{R2}) = -1.087$ From equation (14), $K_{R3} = 0.773$ $T_3 = 236°$ F.
iC_4	0.22	1.63	1.741	0.1263	0.1182	
nC_4	0.10	1.34	1.451	0.0690	0.0636	
iC_5	0.40	0.754	0.865	0.4625	0.4028	
nC_5	0.18	0.650	0.761	0.2365	0.2020	
From equation (11), $f(K_{R2}) = -0.9278$					0.8189	

Component	z	K236°	K+L/V	z K+L/V	zK (K+L/V)²	K238°	K+L/V	z K+L/V
C_3	0.10	2.92	3.031	0.0330	0.0318	2.94	3.051	0.0328
iC_4	0.22	1.67	1.781	0.1235	0.1159	1.68	1.791	0.1230
nC_4	0.10	1.37	1.481	0.0675	0.0624	1.38	1.491	0.0671
iC_5	0.40	0.773	0.884	0.4525	0.3960	0.781	0.892	0.4490
nC_5	0.18	0.665	0.776	0.2320	0.1989	0.680	0.791	0.2280
From equation (11), $f(K_{R3}) = -0.9085$					0.8050	$f(K_{R4}) = \ldots$		0.8999
From equation (12), $f'(K_{R3}) = -1.042$						Therefore, T = 238° F.		
From equation (14), $K_{R4} = 0.781$, and $T_4 = 238°$ F.								

is always +. By substitution of K/K_R for α and referring to Figure VII, we easily obtain,

Equation (18) $\theta(K_R) = \Sigma z/K$

Equation (19) $\theta'(K_R = -(1/K_R)\,\Sigma z/K$

Equation (20) $K_{R2} = \dfrac{-K_{R1}}{\Sigma z/K} + 2K_{R1}$

The procedure for dew point calculations involves the following tabulation:

Component	z	K	z/K

Choose K_{R1} as previously described, remembering that at the dew point, the solution depends upon the summation of the x values, and that the x for the reference component should be the only consideration since V does not enter into the calculations. In many instances, the component with the largest x value will be not only "one of the heavier components," it will be the heaviest component.

Inspection of the general curve of Figure VII will show that, for dew point calculations, an estimate of T_1 which is low by a given amount will yield the answer quicker than an estimate which is high by the same amount.

EXAMPLE 5

Calculate the bubble point of the following mixture at 110 per square inch gauge:

Assume T = 140° F. Choose iC_4 for reference component since y is large.

Component	z	K140°	zK		K151°	zK
C_3	0.045	2.080	0.0936	From eq.[r](17),	2.260	0.1017
iC_4	0.686	1.040	0.7140	K_{R2} = 1.160	1.160	0.7960
nC_4	0.068	0.810	0.0551	T_2 = 151°F.	0.905	0.0615
iC_5	0.071	0.368	0.0261		0.430	0.0305
nC_5	0.007	0.300	0.0021		0.350	0.0024
C_6	0.049	0.120	0.0059		0.143	0.0070
C_8	0.074	0.019	0.0014		0.025	0.0019
		$\phi(K_{R1})$ = 0.8982				1.0000

$T_2 = 151°$ F. is as close an answer as is practical for the degree of precision of the K values used. Obviously, the second summation was not necessary, but it should be made for large differences of temperature between the first estimate and the calculated T_2.

EXAMPLE 6

Calculate the dew point of the following mixture at 170 pounds per square inch gauge.

Assume T = 260° F. Choose iC_5 for reference component since its x value will be the largest. $K_{R1} = 0.920$.

Component	z	K260°	z/K	K236°	z/K	K240°	z/K
C_3	0.10	3.370	0.0297	2.920	0.0343	2.990	0.0334
iC_4	0.220	1.970	0.1118	1.670	0.1319	1.710	0.1288
nC_4	0.10	1.610	0.0621	1.370	0.0730	1.400	0.0715
iC_5	0.40	0.920	0.4350	0.770	0.5200	0.795	0.5050
nC_5	0.18	0.820	0.2193	0.665	0.2710	0.690	0.2610
		$\theta(K_{R2})$ = 0.8579		$\theta(K_{R2})$ = 1.0302		$\theta(K_{R2})$ = 0.9997	
		From equation (20), K_{R2} = 0.767		K_{R2} = 0.793		Therefore, the correct T = 240° F.	
		T_2 236°F.		T_2 240° F.			

Summary of Equations

Method A; see examples 1 and 2.
Given: Temp., Press., Comp.
Find: % Vaporized

V more than 0.5

(1) $V_c = f(V_a) = \sum \dfrac{z}{K + L_a/V_a}$

(2) $f'(V_a) = \dfrac{1}{V_a^2} \sum \dfrac{z}{(K + L_a/V_a)^2}$

V less than 0.5

(4) $V_c = f(V_a) = \sum \dfrac{zK}{K + L_a/V_a}$

(5) $f'(V_a) = \dfrac{1}{V_a^2} \sum \dfrac{zK}{(K + L_a/V_a)^2}$

All V's.

(7) $V_{a2} = \dfrac{V_{a1} f'(V_{a1}) - V_{c1}}{f'(V_{a1}) - 1}$

Method B; see examples 3 and 4.
Given: Pressure, Comp., % Vapor.
Find: Temperature

V more than 0.5

(11) $f(K_R) = \sum \dfrac{z}{K + L/V}$

(12) $f'(K_R) = \dfrac{-1}{K_R} \sum \dfrac{zK}{(K + L/V)^2}$

V less than 0.5

(8) $f(K_R) = \sum \dfrac{zK}{K + L/V}$

(9) $f'(K_R) = \dfrac{L}{VK_R} \sum \dfrac{zK}{(K + L/V)^2}$

All V's

(14) $K_{R2} = \dfrac{V - f(K_{R1})}{f'(K_{R1})} + K_{R1}$

Equations for the bubble point

(15) $\phi(K_R) = \Sigma zK$

(17) $K_{R2} = \dfrac{K_{R1}}{\Sigma zK}$

See example 5.

Equations for the dew point

(18) $\theta(K_R) = \Sigma z/K$

(20) $K_{R2} = 2K_{R1} - \dfrac{K_{R1}}{\Sigma z/K}$

See example 6.

Measurement of Flow of Hydrocarbon Gases

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THE purpose of this article is to show a method of calculating orifice coefficients directly in terms of the equivalent liquid volume.

Because of the great variety of orifice equations in use and the confusion of symbols, the orifice equation for measuring gas flow will be derived so that the reader can apply the method of this paper to his preferred orifice equation.

The basic equation is derived[1] from Bernoulli's equation with the introduction of the coefficient of discharge, C, to correct for friction loss and the difference between orifice and vena contracta diameters.

$$\sqrt{u_o^2 - u_1^2} = C\sqrt{2g\,\Delta H_f} \tag{1}$$

A flow meter with a differential of h inches of water has a mercury differential of h/13.6. If a sealing liquid is used having a density of G_s, the true differential, h′, is

$$\left(\frac{13.6 - G_s}{13.6}\right)h$$

Therefore:

$$h' = 12\,\Delta H_f\,G_f\,\rho_a = \left(\frac{13.6 - G_s}{13.6}\right)h \tag{2}$$

Expressing the flowing gravity of the gas in terms of the ideal (gas-law) gravity at standard conditions (14.7 pounds per square inch and 60° F.)

$$G_1 = \frac{\text{M.W.}}{28.9} \tag{3}$$

$$G_f = \frac{G_1\,P\,520}{Z_f\,14.7\,T} \tag{4}$$

Making this substitution

$$\Delta H_f = \left(\frac{13.6 - G_s}{13.6}\right)\frac{14.7\,T\,Z_f h}{P\,520\,12\rho_a\,G_1} \tag{5}$$

The following relationships are next established:

$$u_o d^2 = u_1 D^2 \tag{6}$$

$$\sqrt{u_o^2 - u_1^2} = u_1\sqrt{\frac{D^4}{d^4} - 1} \tag{7}$$

also

$$u_1 = \frac{Q_1\,\dfrac{14.7\,TZ_f}{520\,P}}{3600\,\dfrac{\pi D^2}{144}} \tag{8}$$

Substituting equations 5, 7, and 8 in equation 1.

$$Q_1 = \frac{3600\,\pi\,C\,D^2}{4\times 144\sqrt{\dfrac{D^4}{d^4} - 1}}\sqrt{\frac{2g}{12\rho_a}\left(\frac{13.6 - G_s}{13.6}\right)\frac{520\,hP}{14.7\,Z_f\,G_1\,T}} \tag{9}$$

Rearranging and substituting $g = 32.16$ and $\rho_a = 0.001224$

$$Q_1 = 338.9\,\frac{C}{\sqrt{\dfrac{D^4}{d^4} - 1}}\,D^2\sqrt{\frac{13.6 - G_s}{13.6}}\sqrt{\frac{520}{T}}\sqrt{\frac{h\,P}{Z_f\,G_1}} \tag{10}$$

The equation can now be written

$$Q_1 = 338.9\,S'\,D^2\,B'\,F_T\sqrt{\frac{h\,P}{G_1\,Z_f}} \tag{11}$$

Another relation which is sometimes used is

$$S'\,D^2 = \frac{C\,D^2}{\sqrt{\dfrac{D^4}{d^4} - 1}} = \frac{C\,d^2}{\sqrt{1 - \dfrac{d^4}{D^4}}} = E'\,d^2 \tag{12}$$

The factor $\dfrac{1}{\sqrt{1 - \dfrac{d^4}{D^4}}}$ is known as the velocity of approach factor.

The constant, 338.9, is for the temperature and pressure base used in the derivation. This is equivalent to the familiar 345.92 for the base conditions of 60° F. and 14.4 pounds per square inch.

The symbols S′ and E′ are here used to indicate that the velocity distribution effect and the compressibility effect are included. Both of these effects depend, among other things, upon the rate of flow and for this reason the experimental determination of C was done under conditions in which these effects were negligible or else were isolated and eliminated. These factors must therefore be applied separately.

$$S' = S\,F_r\,Y \tag{13}$$

Tables are presented in several modifications. In all cases, the value must depend upon the type of taps (flange taps, pipe taps, or vena contracta taps). In some tables[8] S is presented as a function of d/D only. In others[7] SF_r is presented as a function of d/D and the Reynolds number for the average flow. In other tables,[8] $345.92SD^2$ is presented as a function of d and D.

If equation 11 is divided by the constant J, the number of cubic feet of gas equivalent to one gallon of liquid, the equation becomes:

$$V = \frac{Q_1}{J} = \frac{338.9\,S'\,D^2\,B'\,F_T\sqrt{h\,P}}{J\sqrt{G_1}\sqrt{Z_f}} \tag{14}$$

Table 1 lists values of $J\sqrt{G_1}$ for hydrocarbon gases and it will be noted that they are essentially constant for all hydrocarbons containing 6 or less carbon atoms.

This fact means that if 100 gallons per hour of

TABLE 1

HYDROCARBON	G_i	J	$J\sqrt{G_i}$
Methane	0.554	59.1	44.0
Ethane	1.038	41.6	42.4
Propane	1.522	36.5	45.0
n-butane	2.006	31.8	45.0
iso-butane	2.006	30.7	43.5
n-pentane	2.491	27.6	43.6
iso-pentane	2.491	27.4	43.2
n-hexane	2.975	24.3	41.9
Ethene	0.968	44.6	44.0
Propene	1.453	37.9	45.7
Butene-1	1.937	33.8	47.1
iso-butene	1.937	33.9	47.3
Pentene-1	2.421	29.2	45.4
Pentene-2	2.421	29.5	45.9

Values of J were calculated from actual cubic feet of gas per gallon of liquid and gas-law deviation (5).

methane were vaporized and measured with an orifice flowmeter, the chart reading would be almost identical to the reading that would be obtained if 100 gallons of pentane were vaporized and measured under the same conditions of temperature and pressure. It should be noted that a given rate of gaseous methane creates only about one fifth the differential caused by the same rate of gaseous pentane.

Strangely, a mixture of two gases each having identical values of $J\sqrt{G_i}$ will have an average $J\sqrt{G_i}$ somewhat higher. This can be demonstrated as follows:

Nomenclature

$B' =$ correction for sealing fluid $= \sqrt{\frac{13.6 - G_a}{13.6}}$
$C =$ orifice discharge coefficient
$d =$ diameter of orifice, inches
$D =$ diameter of line, inches
$E' =$ defined by Equation 12
$F_r =$ correction for Reynold's number (velocity distribution effect)
$F_T =$ correction for temperature $= \sqrt{\frac{520}{T_f}}$
$g =$ acceleration due to gravity, ft./sec.^{2}
$G =$ specific gravity of gas relative to air
$G_a =$ density of sealing fluid, gm./c.c.
$\Delta H_f =$ differential in feet of flowing fluid
$h' =$ true differential, inches of water
$h =$ meter differential, inches of water
$J =$ cubic feet of ideal gas at standard conditions per gallon of liquid hydrocarbon
M.W. = molecular weight of gas
$P =$ absolute pressure, lbs./in.^{2}
$Q =$ gas rate, cubic feet/hour
$S =$ defined by Equation 13
$S' =$ defined by Equation 12
$T =$ absolute temperature, degrees Rankine
$u_t =$ velocity of gas through line, ft./sec.
$u_o =$ velocity of gas through orifice, ft./sec.
$V =$ equivalent volume of liquid hydrocarbon at 60° F., gal./hr.
$w_H =$ weight fraction of hydrocarbon in gas
$y =$ mol fraction of component in gas
$Y =$ correction for compressibility effect.
$Z =$ deviation from gas law.
$\rho_a =$ specific gravity of air at standard conditions relative to water

Subscripts

a = component a
b = component b
f = flow conditions
H = average hydrocarbon
i = ideal conditions
N = average non-hydrocarbon

$$J = \frac{1}{\frac{y_a}{J_a} + \frac{y_b}{J_b}} \qquad \text{where } y_a + y_b = 1$$

$$\text{and } \frac{1}{y_b} = 1 + \frac{y_a}{y_b}$$

$$G_i = G_a y_a + G_b y_b$$

$$J\sqrt{G_i} = \sqrt{\frac{G_a y_a + G_b y_b}{\left(\frac{y_a}{J_a} + \frac{y_b}{J_b}\right)^2}}$$

By letting $G_a J^2_a = G_b J^2_b$, this can be rearranged to

$$J\sqrt{G_i} = J_a\sqrt{G_a}\sqrt{\frac{\left(\frac{J_a}{J_b} - 1\right)^2}{\left(\frac{J_a}{J_b} + \frac{y_a}{y_b}\right)^2}\frac{y_a}{y_b} + 1} \quad (15)$$

To determine the maximum discrepancy, the derivative is taken and equated to zero.

$$\frac{d\left(\frac{\left(\frac{J_a}{J_b} - 1\right)^2}{\left(\frac{J_a}{J_b} + \frac{y_a}{y_b}\right)^2}\frac{y_a}{y_b}\right)}{d\,\frac{y_a}{y_b}} =$$

$$\left(\frac{\frac{J_a}{J_b} - 1}{\frac{J_a}{J_b} + \frac{y_a}{y_b}}\right)^2 - \frac{2\frac{y_a}{y_b}\left(\frac{J_a}{J_b} - 1\right)^2}{\left(\frac{J_a}{J_b} + \frac{y_a}{y_b}\right)^3} = 0 \quad (16)$$

This is satisfied when $\frac{J_a}{J_b} = \frac{y_a}{y_b}$

Substituting values in equation 15, using methane and n-pentane

$$\frac{J_a}{J_b} = \frac{59.1}{27.6} = 2.13 = \frac{y_a}{y_b}$$

The maximum correction is

$$\sqrt{\left(\frac{2.13 - 1}{2.13 + 2.13}\right)^2 2.13 + 1} = 1.075$$

To extend this mathematical analysis to multi-component mixtures results in unwieldy equations. A few random analyses indicates that the correction is of approximately the same order of magnitude.

To allow for this effect, it is recommended that an average value of $J\sqrt{G_i} = 45$ be used.

Substituting this value in equation 14, we obtain

$$V = 7.531\, S' D^2 B' F_T \left(\frac{45}{J\sqrt{G_i Z_f}}\right)\sqrt{h P} \quad (17)$$

The term $\frac{45}{J\sqrt{G_i Z_f}}$ has been included, but for many purposes, this will be sufficiently close to unity that it may be neglected.

Petroleum gases frequently contain non-hydrocarbons such as hydrogen, nitrogen, carbon dioxide, water vapor, etc. Corrections may be made for these in the following manner: Let y_N be the mol fraction of the total non-hydrocarbon components having an average specific gravity of G_N. J_N will be infinity if it is defined as the number of cubic feet of non-

hydrocarbon gas per gallon of liquid hydrocarbon. The subscript H refers to the average hydrocarbon gas.

$$J = \frac{1}{\frac{y_N}{\infty} + \frac{y_H}{J_H}}$$

$$G_l = G_N \; y_N + G_H \; y_H$$

$$J\sqrt{G_l} = \sqrt{\frac{G_N \; y_N + G_H \; y_H}{\left(\frac{y_H}{J_H}\right)^2}}$$

$$= J_H\sqrt{G_H}\sqrt{\frac{G_N \; y_N + G_H \; y_H}{G_H \; y_H^2}}$$

$$J\sqrt{G_l} = \frac{J_H\sqrt{G_H}}{\sqrt{w_H \; y_H}} \qquad (18)$$

The term $\frac{45}{J\sqrt{G_l}\,Z_f}$ can now be expressed as two factors.

$$\frac{45}{J\sqrt{G_l}\,Z_f} = \frac{45}{J_H\sqrt{G_H}}\sqrt{\frac{w_H \; y_H}{Z_f}} \qquad (19)$$

If this is substituted in equation 17, we have

$$V = 7.531\,S'\,D^2\,B'\,F_T\left(\frac{45}{J_H\sqrt{G_H}}\right)\sqrt{\frac{w_H \; y_H}{Z_f}}\sqrt{h\,P} \qquad (20)$$

TABLE 2

COMPONENT	y	M.W.	J.	$\frac{y}{J}$	y(M.W.)
Nitrogen	.03	28	....	.....	.84
Carbon dioxide	.02	44	....	.....	.88
	.05	..	....	.....	1.72
Methane	.30	16	59.1	.00508	4.80
Ethane	.20	30	41.6	.00480	6.0
Propane	.18	44	36.5	.00493	7.92
n-butane	.15	58	31.8	.00472	8.70
n-pentane	.10	72	27.8	.00360	7.20
n-hexane	.02	86	24.3	.00082	1.72
	1.00	..	....	.02395	38.06

Method 1

$$J = \frac{1}{.02395} = 41.8$$

$$G_l = \frac{38.06}{28.9} = 1.315$$

$$\frac{45}{J\sqrt{G_l}} = 0.940$$

Method 2

$$y_H = 1 - 0.05 = 0.95$$

$$w_H = \frac{38.06 - 1.72}{38.06} = 0.955$$

$$\sqrt{w_H \; y_H} = 0.952$$

$$G_H = \frac{38.06 - 1.72}{28.9 \times 0.95} = 1.32$$

$$J_H = \frac{0.95}{0.02395} = 39.6$$

$$\frac{45}{J_H\sqrt{G_H}} = 0.988$$

$$\left(\frac{45}{J_H\sqrt{G_H}}\right)\sqrt{w_H \; y_H} = 0.940$$

In many cases involving the measurement of hydrocarbon gases, the composition changes from day to day, and more pronouncedly from season to season. Every time the gas gravity changes, the meter factor should be (though seldom is) changed. If the liquid equivalent is required, this conversion factor also must be changed. The foregoing equations demonstrate that the two changes cancel each other insofar as liquid quantities are concerned.

To apply these equations, it is recommended that the meter constant be calculated on a liquid-equivalent basis without regard to gas composition. Corrections for temperature and pressure fluctuations should be made in any convenient manner. The factor would then be the liquid equivalent without corrections for gas law deviation, non-hydrocarbons, or deviations from $\frac{45}{J_H\sqrt{G_H}}$. All of these corrections (in most cases near unity) are dependent upon the gas analysis. Whenever an analysis is made, these corrections can be calculated and used until the next analysis.

In calculating the average value of J, the reciprocal $\frac{1}{J}$ should be averaged and the reciprocal of the answer taken. This is shown in Table 2.

In the example, Z_f was not included in order to simplify the calculation. The calculation was made in two ways. Obviously the first method is easier, but the second method illustrates that the factor is chiefly a correction for non-hydrocarbon gases.

There are several ways of determining Z_f. Values for average natural gases are available in tabular[3] and graphical[4] form. It can also be calculated[4] from the analysis by means of pseudo-critical temperatures and pressures, or it can be most accurately calculated by determining[3] the true critical temperature and pressure and referring to Z curves.[2,6]

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The Role Played by

The Small Refiner In War Production

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FLAG-WAVING, high priorities and official and private acclaim have accompanied the oil industry's spectacular meeting of its part in the war effort. It is no criticism of the propriety of this nor detraction of credit due for what has been accomplished by these specially constructed plants to point out that as "the captains and the kings depart" there will be more stories such as this of the contribution of those who merely "keep on keeping on."

This is the story of a small plant that has been quietly doing its part. Without benefits of priorities either of men or materials, its operations have been revamped to do the job that needed most to be done.

FORTY years ago the methods of operation of refineries and gasoline plants were such that highly trained men were not essential to "getting by." However, the complexities of the new methods of operation, the intricate types of units now on stream demand more than just a "getting by." They demand that even the routine worker have at least a rudimentary knowledge of chemistry and physics as it pertains to natural gases and crude petroleum oils. The trend toward higher pressures and temperatures, the improvement in processing methods, the development of the "cat" cracker and those other types of units, and commercial production of synthetic makes it impossible to employ an untrained man and charge him with the responsibility of operating a unit after a short period of instruction. If plant operation is to be efficient those workmen contributing to that efficiency must have a natural aptitude for technical work in general, as well as training.

In competition with the strides in advanced processing technology has been creation of an indispensably "better-informed" personnel to operate these more complicated processes. The small refiner has had his share in this training of personnel, and it was from the ranks of the men employed by the small refiners that many of the trained workers were recruited to complement the operating personnel of the new wartime units. A great many refiners can show where they actually lost more trained personnel to "defense plants" than they did to the armed services.

Early Aviation Supplies

There was a lapse of time between December 7, 1941, and the summer of 1944 when a large percentage of 100-octane plants were scheduled for completion. During this period the need swelled by many times for this vital material. Naturally, production of high-octane aviation fuel was on the climb, but the major portion of this production was needed at the front. To fill the need at home for aviation fuel that could be used for training purposes, refiners were asked and directed to pour into the manufacture of 87-octane and 91-octane aviation fuel all of their product falling in certain ranges. Many small refiners were able only to manufacture base naphthas that could be shipped to larger plants for blending, while others were so set up that they were able to deliver a finished and leaded Grade 87 or Grade 91 fuel. At the same time, the combination gasoline and distillate plants began to make adjustments in their methods of operation that permitted them to conform with the above mentioned request and direction. A great number of small refiners, gasoline-plant operators, and recycling plants installed lead-blending facilities to permit them to manufacture a specification aviation fuel. Since completion of a major portion of the high-octane program, these refiners, gasoline-plant operators, and recycling plant men have no need for an aviation lead-blending plant because they are not able to produce a grade of fuel such as is in present demand. These installations stand in a great number of cases as only a headstone for the performance of a patriotic duty and can only be in all honesty considered liabilities.

Ingenuity Demanded

Obstacles that appeared insurmountable came up on every hand when changes were considered for the performance of a clearly outlined duty. The inability in a large majority of cases to obtain new materials to carry out proposed changes necessitated application of generous portions of ingenuity in using existing installations and alteration or variation of processing methods to obtain the desired results. The small refiner is on the whole proud of his unsung and unheralded part in the production of aviation fuel during the time of great national need.

Diesel Fuels

Along with the production of aviation fuel came a demand for large quantities of Army and Navy diesel-fuel oils. This demand at times was such that

the refiner was asked by service inspectors if he could in any way increase his production. Once the question was asked, and the evident need expressed, some way was found to make that increased production. The experiences to follow outline the means by which one small Gulf Coast refiner tried to do his bit in the production of military products.

A short resume of the operations previous to September, 1942, gives us a picture of a combination plant encompassing a high- and low-pressure natural-gasoline plant, absorption type, that processed the gas from a high-pressure formation and the attending gas from a low-pressure heavy-crude-oil sand, and a conventional crude topping unit that processed the oil coming from the same two formations. The topping unit was designed to operate on a 2000-barrel-daily throughput and to take from the processed crude a 400° F.-endpoint U. S. Motor gasoline base stock which was blended with the natural gasoline from the absorption unit for distillation and vapor-pressure specification. Other products taken as side cuts from the tower were a commercial grade of kerosine (42-44 gravity), a 0-cold test diesel oil, and a 30-cold test diesel oil, the two being blended on demand to make a 15-cold test diesel oil. The bottoms or residuel fuel oil taken from the base of the tower completed the product cycle.

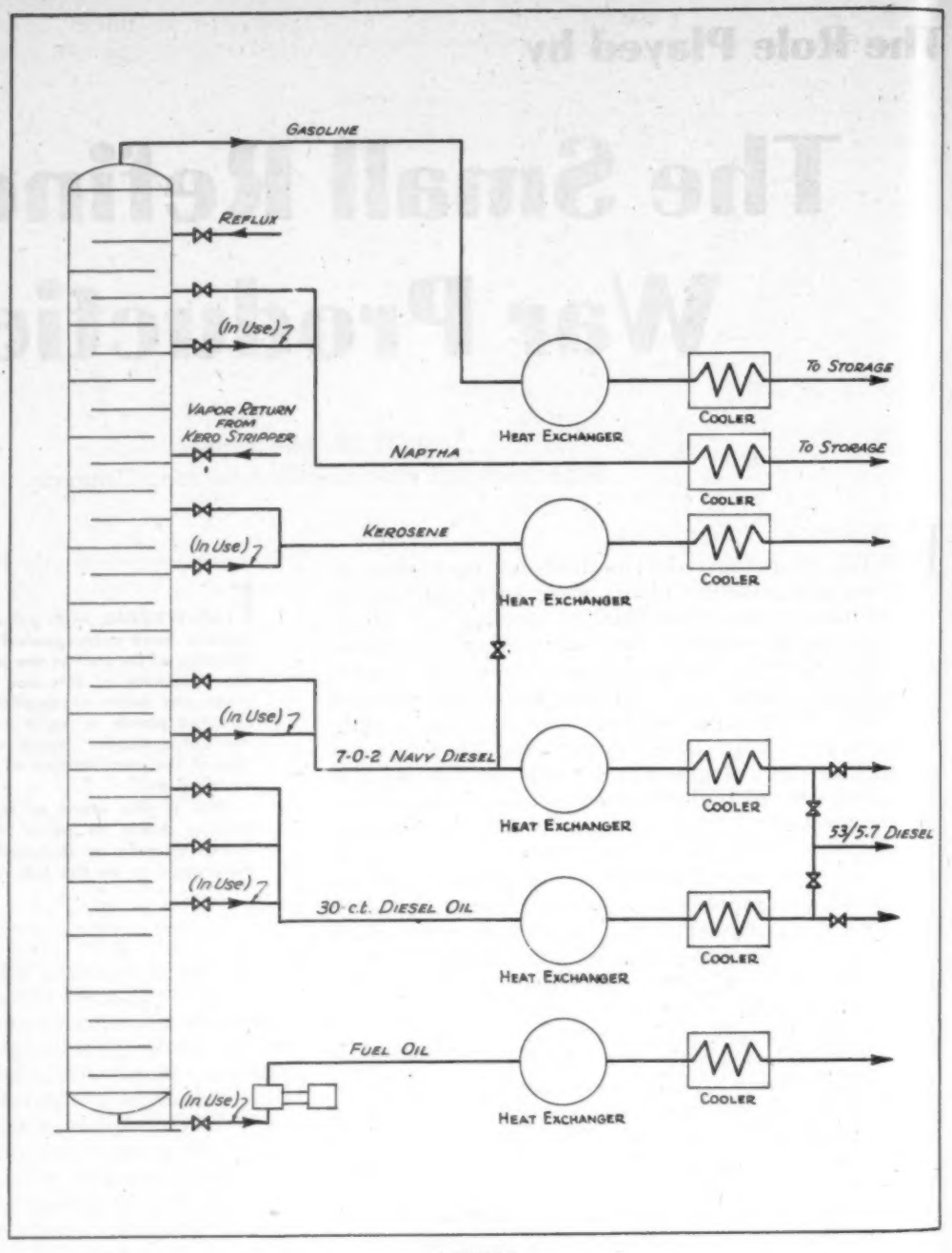

FIGURE 1
Tower-pull details previous to September, 1942

In September, 1942, it became apparent that either a Grade 87 aviation fuel would have to be made as a finished product, or as a base stock ready for lead blending. A shift was made in the side-tower pulls so that the 2000-barrel daily throughput could be maintained and a 275° F.-endpoint overhead stream taken. This endpoint specification being the maximum that could be made and by leading with 4 cc. of tetraethyl lead (then the maximum amount that could be used) secure an 87-octane aviation fuel. This change in side-pulls necessitated taking a naphtha stream between the overhead gasoline and the kerosine side stream. This naphtha stream carried a specification such that its distillation range fell between 230° F. initial-boiling point and 350° F. endpoint. By taking this range of product a kerosine of 510 to 525° F. endpoint with a flash of 125° F., closed cup, and an initial of 330° F. could be secured. On down the tower below the kerosine pull the two diesel-oil streams continued to be taken as usual, as was also the residual-fuel-oil stream. Later, the maximum amount of lead that could be added per gallon was raised to 4.6 cc., and when this was done, the overhead gasoline endpoint was raised to 295° F., which in turn permitted taking a closer cut on the naphtha stream of 350 to 360° F. initial and 350 to 360° F. endpoint.

Hot Blending in Stabilizer

As has been previously mentioned, in operations before September, 1942, the gasoline made at the topping plant was blended with the natural gasoline taken from the absorption units. However, in the manufacture of 87 grade aviation gasoline, it was necessary to hold a maximum 7.0 pounds per square

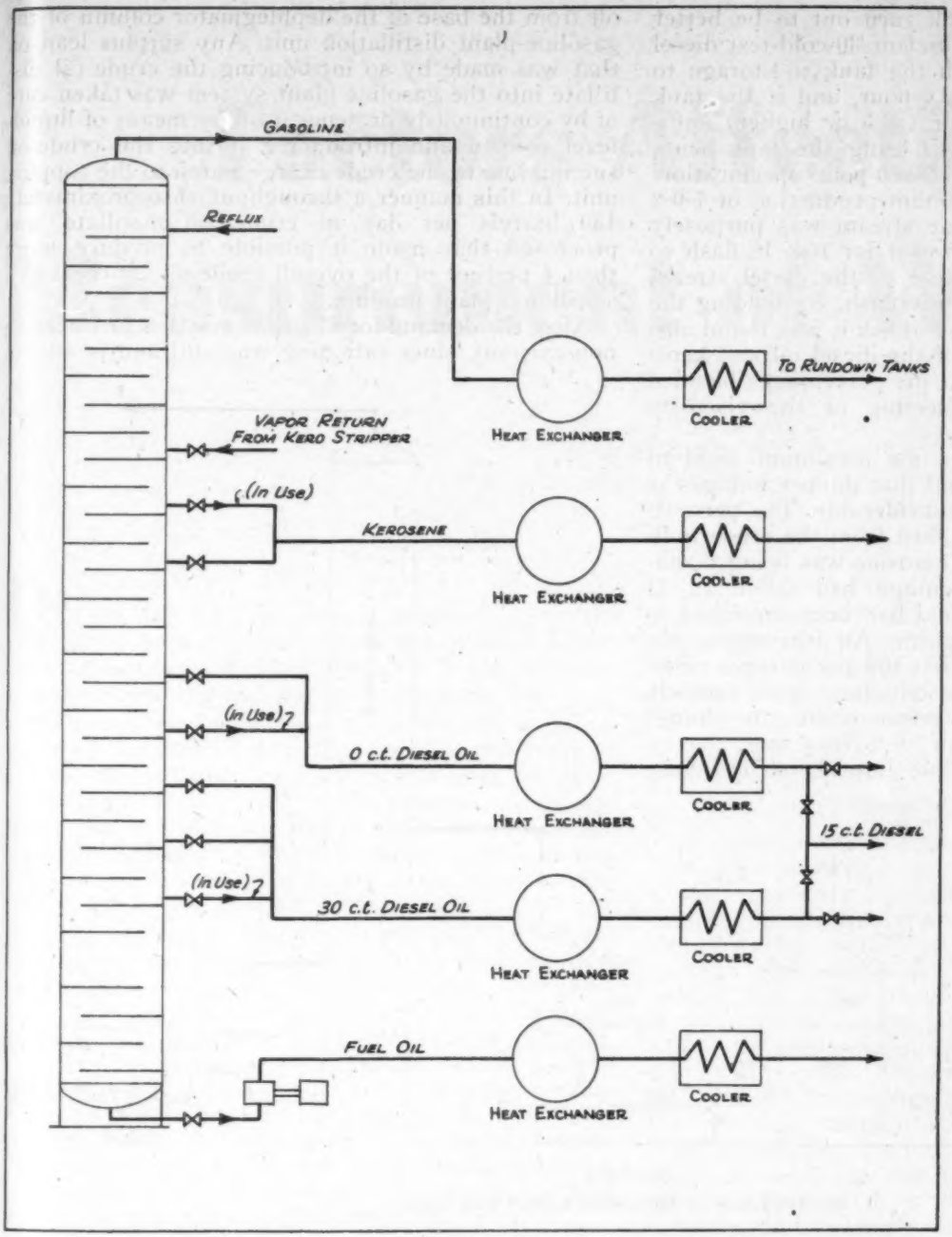

FIGURE 2

Tower-pull details when making aviation base stock and Navy diesel oil

inch vapor pressure as one of the specifications. The thought occurred that this could be most easily and efficiently done in the stabilizer itself. Therefore, a 6 x 4 x 6 duplex steam reciprocating pump was set to take suction on the raw overhead gasoline run-down tank at the topping unit and charge this raw gasoline direct to the stabilizer for hot blending and stabilizing with the raw natural gasoline from the absorption units make-tank. This charge was controlled from both raw tanks by flow controllers and the discharges from both charging pumps came together just previous to the heat exchanger attendant to the stabilizer unit. The blend of raw materials was introduced in the stabilizer at the same point and were processed together to meet 87 grade aviation base stock specifications. For a number of months, the base stock was moved to a larger refinery by transport truck where facilities for lead blending were available. In the spring of 1943, however, priorities were secured for the construction of aviation lead blending facilities and by the first of June a finished aviation fuel was being moved direct to the Army Air Forces. This movement of Grade 87 material continued until in November, 1944, when the Army began using a higher grade material.

The demand for Navy Grade 7-0-2 Diesel Fuel during the period from September, 1942, until November, 1944, was heavy, and naturally the proper contacts were made in regard to the movement of that grade fuel to the Navy. At the time of the first contact the figures given as to the quantity of this material that could be produced were based on the material that could be taken as a direct stream from the fractionating tower. However, after two or three shipments had been made, the inspecting officer remarked that the need was acute for additional supplies of 7-0-2 grade and inquired if shipment was being made of the maximum amount of material that the plant could produce. He was told that the matter of increasing the percentage of specification product required would be looked into and that he would be advised.

Figures compiled regarding the percentages of cuts taken from the crude as the plant was then being operated indicated that 21 percent of the crude was going into kerosine, 23 percent into gasoils or commercial diesel oils, and only 3 percent was being manufactured into 7-0-2 Navy grade. Some laboratory evaluations indicated that it would be possible to substantially increase the 7-0-2 material by blending, and yet maintain all of the test points.

Some additional connections were installed in the tank farm so that circulation of the storage tanks could be obtained after each new pumping. Additional by-pass connections were installed between the fractionating tower and the heat exchangers on the side streams so that a proportionate blending of the hot fractions as they came from the tower could be procured. This new operating procedure permitted the cutting of the normal 0-pour side stream for approximately a 10-pour and by blending back with a portion of the kerosine side-stream meet 7-0-2

specifications. Should a tank turn out to be better than (less than) 0-pour, sufficient 30-cold-test diesel oil was pumped along with the tank to storage to bring the material up to a 0-pour, and if the tank should be more than 0-pour (+ 5 or higher) sufficient kerosine was added to bring the tank being transferred down to meet the 0-pour specification. During this period of maximum production of 7-0-2 Navy diesel oil the kerosine stream was purposely processed in the stripping tower for 150° F. flash so that any addition of kerosine to the diesel stream would not adversely affect the flash. By holding the kerosine stream above 150° F. flash it was found also that the natural viscosity of the diesel oil and kerosine streams were such that the percentages blended permitted a continuous meeting of the viscosity specification.

After a three-month run for maximum yield of Navy 7-0-2 fuel, it was found that the percentages as given above had changed considerably. The percentage of cuts as now being taken from the crude indicated that only 13 percent kerosine was being manufactured, the gasoil percentage had fallen to 11 percent, while the 7-0-2 yield had been increased to slightly more than 23 percent. An interesting observation at this point is that the percentages of all other products being taken remained approximately the same as they had been before making the change over for maximum yield for 7-0-2 Navy fuel.

An item of constant prime importance has been

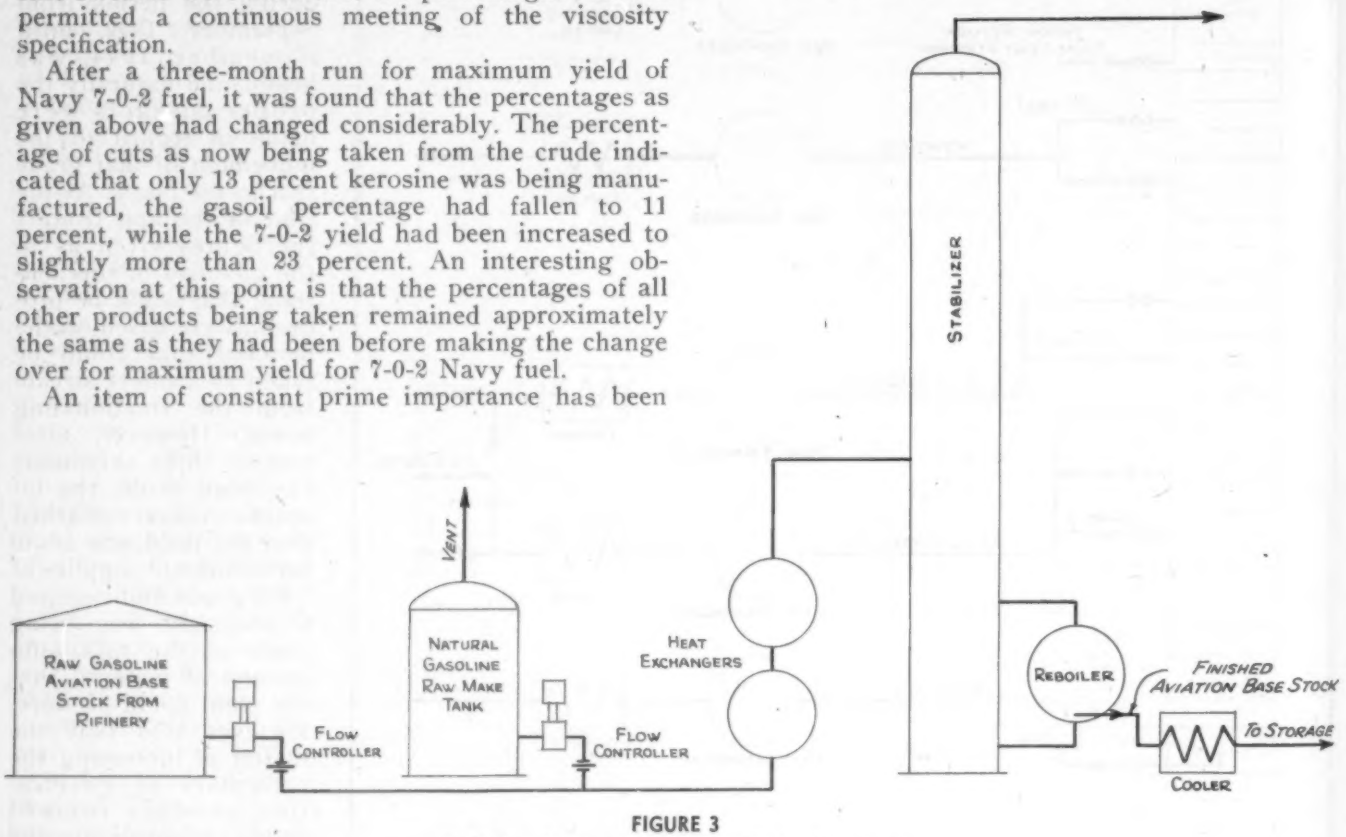

FIGURE 3
Stabilizing hook-up for finished aviation base stock

the increasing necessity to increase the amount of crude run through existing equipment. As has been stated previously, the particular plant under discussion was in conjunctive operation with a conventional absorption gasoline plant. A water-white, or near water-white crude distillate oil was available for processing and there also existed a market for a product of approximately 200° F. initial boiling point and carrying an endpoint of approximately 500 to 510° F. The distillate crude oil was of considerably lower initial than 200° F. and also had an endpoint of much more than 500 to 510° F. In order to make it meet the desired specifications, a way of processing it without interfering with the operations of either plant so far as maximum yield of products and maximum throughput were concerned had to be found. It was determined that by introducing the crude oil distillate into the high-pressure vent tank with the rich oil from the two absorption systems so that it could travel with the rich oil through the heat exchangers attendant to the gasoline plant still and flashing it off with the gasoline, a product with the desired characteristics could be continuously drawn off from the base of the dephlegmator column of the gasoline-plant distillation unit. Any surplus lean oil that was made by so introducing the crude oil distillate into the gasoline-plant system was taken care of by continuously drawing it off by means of liquid-level control and introducing it into the crude-oil suction line to the crude-charge pump to the topping unit. In this manner a throughput of approximately 150 barrels per day of crude oil distillate was processed that made it possible to produce more than 4 percent of the overall crude-oil charge as an additional plant product.

After the demand for 87-grade aviation fuel became non-existant, since rationing was still and is still in effect, the movement of the gasoline that must now be moved as a motor fuel or as a special specification product became for a short while a major problem. However, by installation of a small stripping unit composed of a heat exchanger and a stripping vessel a product with a 200° F. initial and a 360° F. endpoint was made to fill a developed demand for an unrationed naphtha. The raw gasoline made in the topping unit was charged through the heat exchanger where exhaust condensate from the dephlegmator passed counter currently and then was introduced into the flashing chamber. Here the initial desired was secured by the introduction of live steam in such quantity as was necessary to obtain the required initial specification. The vapors driven off in the steam flashing operation were carried into the dephlegmator by means of a vapor-relief line and were consequently condensed with the gasoline fractions coming from the natural gas absorption plant; finally, after being processed along with the natural gasoline in the stabilizer, becoming a part of the motor fuel product that was made into respectively U. S. Motor, regular or Ethyl.

Factors Affecting Measurement of Wet Gas

T. C. SHAW
Arch Petroleum Company

DETERMINING the flow if fluids is one of the three most important measurements required by industrial instruments, the other two being temperature measurement and pressure measurement.

There are two primary reasons for the measurement of the flow of gas: To establish the ratio or volume needed into a continuous process or to an established market, such as the amount of wet gas into a plant or to a pipe line so the plant or pipe line can be technically operated, based on these volumes, and to determine the disposition of the material relative to the cost settlement or payments.

The use of gas as fuel and as process material has created an important application for flow meters, and in this service it naturally requires extremely high operating efficiencies. Since the products measured usually are sold on the basis of meter readings, it becomes essential for gas engineers to have a sound knowledge of the fundamentals of flow-meter mechanisms and to be able to compute the flow of fluids through differential-type flow meters without error. The number of variables that can influence the accuracy of flow-meters are numerous, and mastery of this subject is not easily accomplished.

Measurement Factors

There are a number of factors that have a pronounced effect on the problem of wet gas measurement, principally in determining the coefficient to be used. Factors considered most important are:

1. Density of the fluid passing through the orifice.
2. Pulsating flow.
3. Deviation from the true gas law.
4. Correct reading of the charts upon which the pressure and the differential are recorded.

The first three of these factors are of extreme importance in determining the proper coefficients to be used in wet-gas measurement, while the fourth is a mechanical problem that has no bearing upon the flow of the fluids, but entirely upon the computation of the results recorded by the meter.

Probably one of the greatest errors in measurement of high-pressure wet gas is the density or gravity factor of the gas to be measured. The only way the industry has had in the past to determine the specific gravity in the orifice coefficient for high-pressure distillate-bearing gas has been to analyze a sample and have the testing laboratory submit a theoretical specific gravity based on the percent of different hydrocarbons in the gas so analyzed. This method is necessary because condensate would precipitate out and the specific gravity would not be accurate if measured in the conventional way by a gravity balance.

Density of Fluid

It has been the experience of testing laboratories that, after running a sample of wet-gas-bearing distillate, they have found quantities of water in the sample containers after analysis of the gas. The quantity of water naturally would bear some relationship on the coefficient for specific gravity and it would be proportional to the amount of water in the container. In many other instances, though the gas containers had been heated, some distillate remained in the containers. This, also, would bear a small relationship on the coefficient which should have been used for the specific gravity of that cubic foot of gas. In other words, the specific gravity of gas as weighed could be much heavier than the actual theoretical specific gravity of the gas analyzed due to water and to heavy hydrocarbons that have precipitated from the gas.

The same trouble was experienced in the Gulf Coast in a cycling plant where the error of measurement was relatively high. After testing the wells for determining the gasoline content, it was noted the wells were making a quantity of water, which the separator was catching. This separator was operating at approximately 1200 pounds, gauge, and only a few degrees above the hydrate-forming point in order to obtain an efficient separation. It was decided, after numerous tests throughout the field, that evidently water vapors were materially affecting the measurement, and for accurate measurement it would be necessary to determine the exact quantity of water in a vapor phase and entrained with the gas being emitted from each well each hour. A test separator was devised so that it could be run with very low pressure and comparatively low temperature in order that the water vapor in the gas might be trapped. Next step was to take a core sample of this gas, matching, of course, the velocity of the gas through the test separator with the velocity of the gas flowing through the field line to the plant, and continuous

samples were run until the exact amount of water in each cubic foot of gas was determined.

Accuracy Gained

Simultaneously, the tail gas from the separator was weighed by a balance intermittently during this test. The result of the gas weighed by the balance and the specific gravity of the distillate trapped in the separator and the specific gravity of the water which was also accumulated in the lower section of the separator, were used to determine the true specific gravity of one cubic foot of gas going through the the orifice meter. This error, in one instance, ran as high as 15 percent on one well and it was necessary to correct the specific gravity factor on all the meters of the five wells tested. After the survey was completed and a new specific gravity was applied into the coefficient, this plant balanced within one percent based on the incoming gas to the gas going back into the sand.

D. A. Sillers of Lone Star Gas Company made reference to these findings before the Natural Gasoline Association of America at Dallas in April, 1943. It was found that the specific gravity as determined by tests, was not as sensitive as the distillate-content test. Where the specific gravity of the residue gas as processed was found to be .642, the specific gravity of the two-phase gas was .680. It will be noted, however, that the accumulated liquid accounted for .038 in the total results, so that error in conducting the test would be reduced to about 5½ percent of that error in the final results.

The problem of specific gravity probably is more severe in some fields than in others. In wells making little water, the error would be much less than in wells showing considerable quantities of water vapor; therefore, to the gas engineer falls the responsibility of determining whether the gas to be measured is high or low in water vapors.

Another way to make an actual and true gravity on high-pressure wet gas would be to devise a cylinder in connection with the flow line with a sampling connection inserted in the flow line, and actually catch and weigh the gas contained in the cylinder. This, possibly, has never been tried, but it would seem to be feasible and possible as scales accurate enough to weigh gas are available in many plant laboratories.

Pulsating Flows

It is often found in practice that the flow of gas to be measured is pulsating because of the action of reciprocating compressors delivering the gas, or some other causes inherent in the process. A condition of this kind inevitably will produce a large error in the measurement of the flow of gas in a differential-pressure meter.

There is little experimental data available for correcting the flow coefficient for pulsation and, therefore, any correction for this condition will have to be based on theory and may or may not give an accurate correction for the flow. Naturally, the best way to reduce the error is to eliminate the cause or minimize pulsation by the use of chambers of sufficient size to stabilize the pressure.

Damping devices are standard equipment on all differential-type meters, but in addition to these damping devices it has been found that pulsation pots on the up-stream and down-stream lines help materially in reducing the pulsation factor. This device comes off the orifice flanges into the pulsation chamber and into a slotted line running parallel with the pulsation chamber, and is slotted downward at about 45-degrees. The damped gas comes off the top of this chamber to the orifice meter. A drain is provided in the bottom of the chamber so water or distillate can occasionally be drained. This type of chamber was first used by Henderson Company at its Agua Dulce plant near Banquette, Texas. Before installation of these chambers, the plant balance showed it was injecting into the ground sometimes as much as 20 percent more gas than was being processed by the plant. Careful consideration had been given the measurement of the incoming gas, and it was assumed that this measurement was fairly correct. After installation of the chambers, on the discharge headers of the compressor going to the injection well, the error was substantially reduced, and most of the time a complete balance of incoming to outgoing gas could be obtained at this plant.

Another thought to minimize the effects of pulsation, would be the installation of a secondary orifice, 50 to 75 pipe diameters ahead of the orifice used for measuring the gas flow. Use of a secondary orifice will cause a small pressure drop in the line and, to be effective, it should be designed to produce at least a three-to-four-pound pressure drop. Professor Bitler of Ohio State University ran experimental tests in conjunction with the Natural Gas Association, and found that by using a smaller orifice with a wider differential, say as high as 0-300, but in all cases carrying the differential above 100 inches, he was able to greatly minimize pulsation caused by reciprocating compressors, and pulsation flows were greatly improved.

Another method for the elimination of pulsation is by the installation of two meters, one on the flow line and the second on a Y, dead-ended. Both meters are put into service and the differential shown on the dead-ended meter is subtracted from the differential on the meter that is measuring the total flow. It is assumed in this case that the dead-ended meter will show a slight differential due to pulsation, and the differential shown due to pulsation will be the same pulsation in the meter that is on the line.

All of these methods are effective and will assure better reading if properly installed. If it is impossible to eliminate pulsation from the meter by methods outlined, the only other alternative is to study the matter and make a correction for this condition.

In most cases of pulsating flow, the reading on the flow meter will be in error on the high side except in case of extremely slow pulsation, which is never encountered on gas compressors, as the pulsation there is too rapid to be followed by an orifice-meter mechanism. It has been found that if the cycle occurs as rapidly as 50 pulsations per minute or above, the ordinary mercury-filled orifice flow meter will not respond to each pulsation. This is due to inertia of the mercury. This condition will increase in severity as pulsation increases in rate.

Evaluating the Error

The theoretical evaluation of the error resulting from pulsation may be made as follows: If it is assumed that the pulsations are of a nature that permits the maximum flow for half of the time and no flow for half of the time, this cycle can be represented as 50 percent. It is also known that the relation between flow and pressure differential for all pressure-differential-type meters is parabolic. The curve of flow from 0 to 100 percent is plotted against the pres-

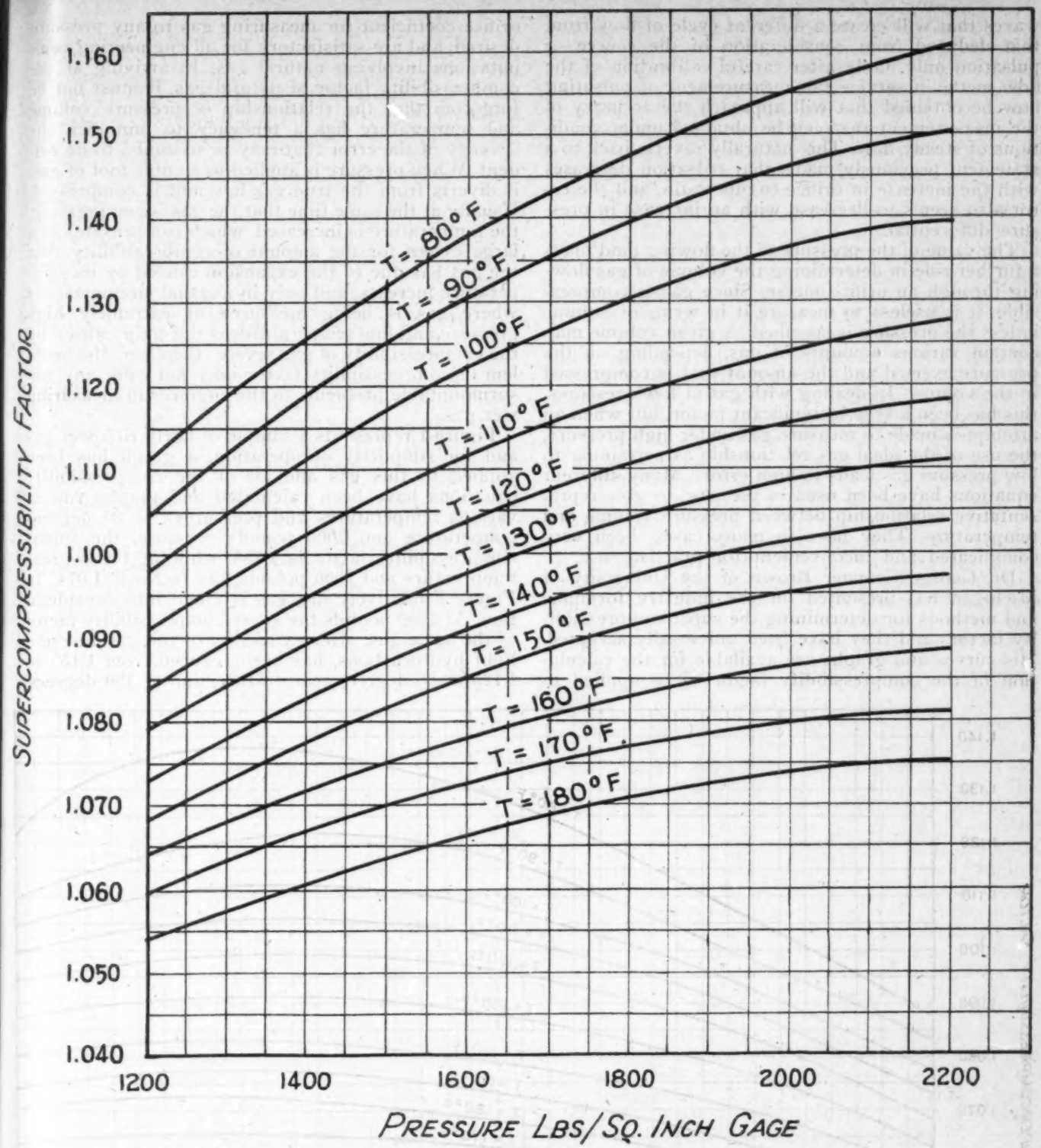

FIGURE 1

Supercompressibility curves for Michna 7 well stream flow, 5800-foot sand.

$$F_{pv} = \sqrt{\frac{1}{z}}$$

Volume percentage: Methane 90.935, Ethane 3.867, Propane 1.702, I-butane 0.684, N-butane 0.482, Pentane and heavier 2.330, Total 100 percent.

sure differential from 0 to 100 percent. Under the condition of the flow outlined above, the meter will record an average pressure differential of 50 percent of the total head. However, owing to the parabolic characteristics of the flow, this average pressure will represent 70.7 percent of the total flow which is found by extending the ordinate to the flow curve at the point of 50 percent of maximum differential. The reading under this condition of flow is, therefore, 41.4 percent higher than would be the case if the instrument were sufficiently sensitive to record the true differential, or if the same flow were being delivered at a steady rate.

This simple illustration also can be applied to pulsation due to the action of a reciprocating pump. The cycles may be calculated on the data available on its speed and valve action. However, it is much better actually to calibrate a flow meter measuring the pulsating flow since the inertia of the fluid or gas and the capacity of the system may induce pressure

waves that will create a different cycle of flow from that deduced from consideration of the source of pulsation only. Only after careful calibration of the flow meter in service can measurement of pulsating flow be obtained that will approach the accuracy of the measurement that can be obtained under conditions of steady flow. This naturally reverts back to a statement previously made, that pulsation decreases with the increase in orifice-to-pipe ratio, and the error also seems to decrease with an increase in pressure differential.

The value of the pressure of the flowing fluid plays a further role in determining the volume of gas flowing through an orifice meter. Since gas is compressible, it is useless to measure it in terms of volume unless the pressure is specified. A given volume may contain various amounts of gas, depending on the pressure exerted and the amount that is compressed in the volume. In dealing with gas at low pressures, this has been a very insignificant factor, but when an attempt is made to measure gas under high pressure, the use of the ideal gas relationship as pertaining to low-pressure gas leads to high errors. Many different equations have been used in the past to give representative relationship between pressure volume and temperature. They have in many cases, been very complicated and inconvenient for practical use.

Dr. George Granger Brown of the University of Michigan has presented for the industry formulae and methods for determining the super-compressibility factors and they have been universally accepted. His curves and graphs are available for the calculation of the compressibility factor to be applied to orifice coefficient for measuring gas to any pressure desired, and are satisfactory for all engineering computations involving natural gas. In arriving at the compressibility factor of natural gas, it must not be forgotten that the relationship of pressure volume and temperature has a tendency to minimize the severity of the error that may be assumed to be evident. When pressure is applied to a cubic foot of gas, it diverts from the true gas law and is compressed. Usually at the same time that the gas is compressing, the temperature is increased, which compensates to a large extent for the amount of compressibility that the gas has due to the expansion caused by its temperature increase, and only in unusual circumstances where gas is being measured at extremely high pressure and low temperatures is the error caused by the compressibility of gas severe; therefore, the problem of compressibility factor does not offer any unsurmountable problems to the engineer in measuring wet gas.

Figure 1 represents a sample of fairly rich wet gas and for simplicity of operation, a graph has been applied to this gas and all of the compressibility equations have been calculated and graphs run at various temperatures and pressures. At 80 degrees temperature and 2000 pounds pressure, the super-compressibility factor is 1.155, while at 180 degrees temperature and 2000 pounds, the factor is 1.074. In Figure 2 relatively dry gas is taken into consideration. At 2000 pounds the super-compressibility factor of the same gas, after extraction of the gasoline and light hydrocarbons, has been reduced from 1.155 to 1.125 at 80 degrees temperature, and at 180 degrees,

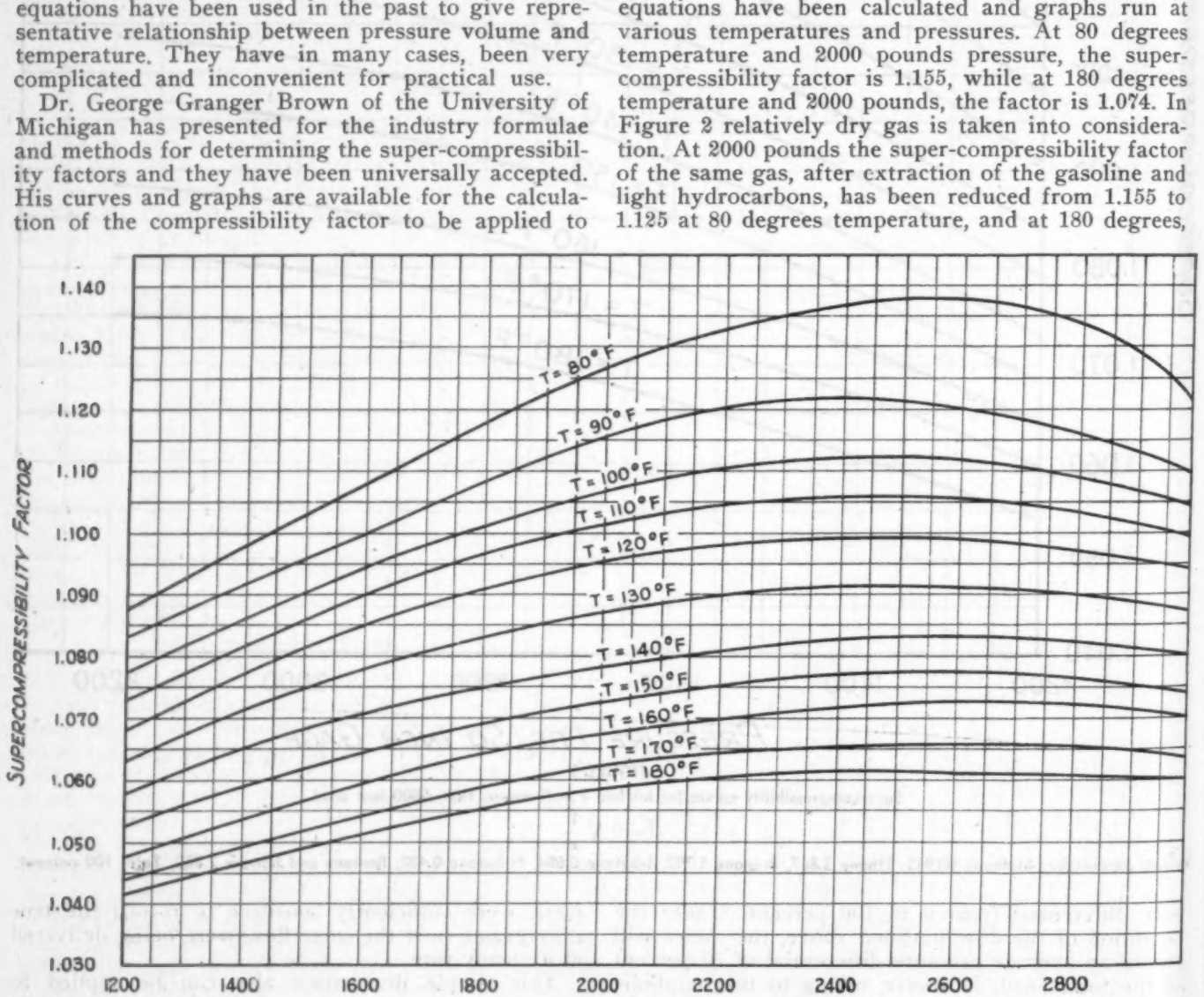

FIGURE 2

Supercompressibility curves for residue gas high pressure Absorber No. 2,

$$F_{pv} = \sqrt{\frac{1}{z}}$$

Volume percentage: Methane 95.74, Ethane 2.67, Propane 1.06, Iso-butane 0.21, Iso-pentane 0.05. Total 100 percent.

the compressibility factor has been reduced from 1.074 to 1.058. From these two graphs it is easily seen that considerable error can be encountered in the compressibility of gas if the temperature is low and the pressure is high, but if the temperature increases and the pressure remains constant, the error is substantially lower.

Chart accuracies are an important factor in accurate flow measurements regardless of operating pressures. Charts for any make of meter should be held to very close tolerances. This would be equivalent to having all charts printed from one master plate.

In the calibration of flow-recording instruments, identical travel for the various pressure and differential ranges is imperative. Charts should be concentric in both the printing and punching so that proper zeroing and testing of instruments can be accomplished without taking into account the average conditions in the field. Apparently, the seven-point chart, which is made of heavier paper, is more suitable for all operating conditions than charts made of lighter paper.

Chart reading also has a definite bearing on flow-measurement accuracy. After the charts are once recorded, the reading is sometimes referred to as an accounting procedure. The three methods most commonly used for reading charts are the following: Observation, planimeter and integrator. The first two methods are satisfactory for rough operating purposes, but are fundamentally incorrect if the pressure and differential of the flow recorded show an appreciable amount of fluctuation. The integrator is conceded to be the most accurate method of reading charts. It is also much faster and eliminates possible disputes in chart calculations which so frequently arise from charts read by other methods.

Flow-meter measurement is a problem in which a number of errors can occur; therefore, each step which will eliminate these possibilities is a definite improvement toward accomplishing measurement perfection.

The four factors: Density of the gas, pulsations in the lines, deviation from the true gas law, and correct reading of the charts, probably contribute more to the various problems and errors encountered in wet-gas measurement than any other thing.

In measuring wet gas at high pressures, principally gas that is distillate-bearing, a retrograde phenomenon is encountered that has caused trouble. Briefly, when this form of measurement was entered into, difficulties were encountered caused by hydrocarbons going out of the solution and liquid accumulating behind the orifice plate. Several methods were introduced at that time, one being that horizontal meter runs were quite satisfactory provided weep holes were bored in the bottom part of the orifice plate to allow the condensate to emit through the orifice plate, which would eliminate to a great extent the restricted area on the up-stream side of the orifice plate. This condition has happened in many cases and has affected the measurement materially.

Another method to correct the effect of condensate on the up-stream side of horizontal meter runs was to use vertical-type meter runs. This method has been pretty well accepted as standard where wet gas at high pressures is being metered. In horizontal meter runs, however, it has been found that in most all cases where condensate is built up behind the orifice plate, usually there has been a marked decrease in pressure from the well head to the orifice connection, and naturally, when the pressure is reduced on this type of gas, condensate will form. If the pressure is maintained at well-head pressure as far as the down side of the meter run, it is reasonable to assume that very little condensate will accumulate in the meter run, and accurate measurement can be obtained by the use of horizontal meter runs and they are, under this type of operation, just as satisfactory as vertical meter runs.

Another problem that has been encountered in high-pressure-gas measurement, and is usually multiplied to a great extent if the orifice plate and meters are close to the well, is the cutting action of sand usually emitted from a high-pressure condensate well when the rate of flow is materially stepped up as it is in some cases. This cutting action takes place to a certain extent constantly on the orifice plate in the line from a high-pressure gas well, and of course, the closer this plate is to the well, the greater the cutting action. A number of errors in measurement have been traced directly to the fact that the orifices, as sized in the various meter runs, have been enlarged due to this cutting action. When they were removed and new plates installed, the plant balance came back to a balance where very little error was encountered.

There is no predetermined time when orifice plates should be measured and checked. The operator of the field has a better knowledge of this condition than anyone, as he knows the rate of flow, the irregularities in measurement and peculiarities in wells and sands from which they are producing, but it might be well to bring out that this one small thing has in many instances caused errors in gas measurement in Gulf Coast cycling plants.

When measuring wet gas at high pressures, due to the hydrate point of the various hydrocarbons at elevated pressures, considerable trouble has been experienced even in the South Gulf Coast, due to the freezing of meters. Numerous corrective measures have been taken to eliminate this trouble. Seal pots where glycerine or other non-freezing solutions have been used in order to eliminate the hydrates forming in the meters and cutting off the differential across the meter. Some of these methods, of course, have merit, but it is difficult to use any non-freezing seal-pot liquid without the same finally being contaminated and displaced with gasoline or connate water. It has been found that the best solution for eliminating hydrate freezing trouble on high-pressure-gas meters, principally in recycling plants where the meters are close to the wells and the wells are flowing from a deep horizon which is relatively hot, is to install an insulated house over the meter run, and if necessary, install fins to radiate the heat. These should be tacked to the outside surface of the meter run inside the meter house. It has been found that, where 135-degree gas is coming from the ground with a well-insulated and well-radiated meter house, the temperature inside can be maintained as high as 125 degrees, at which temperature very little hydrate trouble can be expected. These meter houses are relatively inexpensive. A door should be provided for changing charts, and the upper half of the house hinged so that it may be unbolted and pulled away from the meter so that it may be serviced. The bottom section of the house should be permanently attached to the meter run as it would only be necessary to remove this in the event plate changes were necessary. Then, in addition to the insulated house, the accepted practice now is to use in the seal-pots of the meter condensate that is the same as in the gas.

DESIGN FOR EFFICIENCY IN A Routine Control Laboratory

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THE average refinery routine control laboratory is created by moving the necessary equipment into whatever kind of building happens to be available at the time, and adding equipment and possibly an annex as the need arises; few such organizations have the chance to plan their buildings from the ground up. The personnel of the Baton Rouge Refinery Laboratory, Louisiana Division, Standard Oil Company of New Jersey, was, however, placed in just that enviable position when it became evident, as plans grew for the expansion undertaken by the company as a part of the war effort, that the space and manpower available for testing and control work would be totally inadequate. Lack of suitable space for additions to the old laboratory building made the construction of an entirely new building necessary and brought to M. B. Amis, chief chemist, and members of his staff the opportunity to lay out their working space, at least temporarily, just as they wished. The arrangement of the various rooms within the main building and the selection of furniture was left entirely to the laboratory personnel so that the exact requirements peculiar to this type of work could be met.

Function and Organization of the Refinery Laboratory

The function of the laboratory described here is strictly one of routine control; research and technical service work are done by other groups within the company organization. The considerations involved in the construction of the building therefore apply only to this one type of work. The laboratory has a total of 168 workers, 104 of whom are analysts and testers. The organization is broken down into smaller groups which are listed below, with a brief description of the type of work performed by each:

1. *Light Oil and Fuel Oil Group.*

The usual physical tests on gasolines, solvent naphthas, kerosine, tractor fuels, gasoils and residual fuels, including API gravity, ASTM distillations, viscosities, vapor pressures and the like.

2. *Asphalt Testing Group.*

All tests on asphalts and road oils and, in exception to the general rule, a certain amount of experimental work related to the development of special grades.

3. *Gas Analysis Group.*

All light hydrocarbon analyses including low-temperature Podbielniak distillations, Orsat analyses, specification testing of butadiene, heating values, and spectrometric analyses.

4. *Lubricating Oil Group.*

The usual physical tests on lube oils.

5. *Analytical Group.*

This group performs more or less chemical tests on all products and a wide variety of other tests and special analyses such as identification of deposits from the operating units. Some idea of the variety of the routine work performed by this group may be formed from the following very incomplete list:

Tetraethyl lead in gasoline.
Plant acid for carbon, acidity, water.
Salt in crude.
Sulfur determinations, "bomb," and "lamp."
Oxidation stability tests on lube oils.
Propylene in ethylene.
Oxidation stability of aviation gasolines.
Type analysis of gasoline (aromatics, naphthenes, paraffins and olefins).
Wax testing.
Grease analyses.
Corrosion tests.
Gum contents on gasolines.
Stability of residual fuels.
Stability of distillate fuels.

No mention has been made of the knock-testing group, which also comes under the supervision of the refinery laboratory. This group was adequately housed in a separate building (as it should be) when

From 1909—

Ben Higginbotham, recording reminiscencies of growth of the laboratory which kept pace with the refinery at Baton Rouge in a recent issue of "The Stanoclan," employes' publication, collected data from which Bon Dickey drew the accompanying sketch, and from which Higginbotham wrote:

The first laboratory was a 16 x 16.

"The first laboratory at the refinery was a 16 x 16 frame building which was situated near the old "Dixie" gate. Alphonse Scheidecker, a native of Alsace-Lorraine, and a very able man, had come from Beaumont, Texas, to be the first chief chemist, and Mac Anderson (Docks) had come from Vanderbilt University to be his first assistant and helper.

"Mr. Anderson did double duty as oil tester and first-aid man, and, when the laboratory was established on its old site in 1910, he had one room set aside which served as a combination chief chemist's office, sulphur-determination test room and hospital."

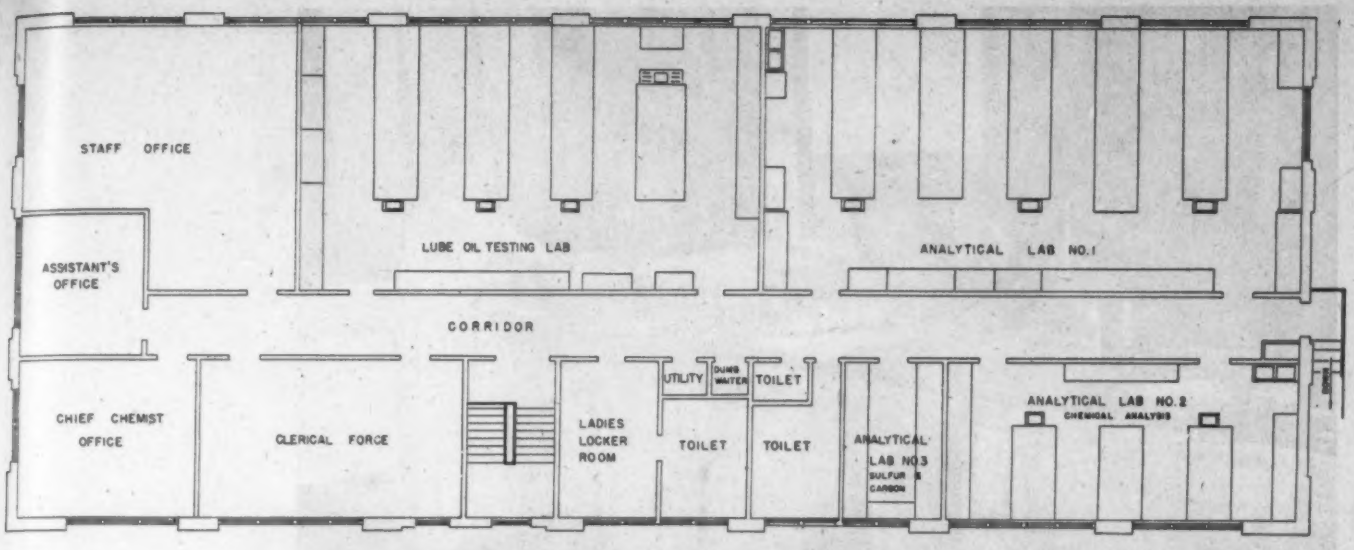


FIGURE 1

Floor plan of the control laboratory, Baton Rouge Refinery. Sketches at the top and bottom of the page show arrangement of the two floors and provision for convenient sample distribution.

FIGURE 2

Light oil and fuel oil section.

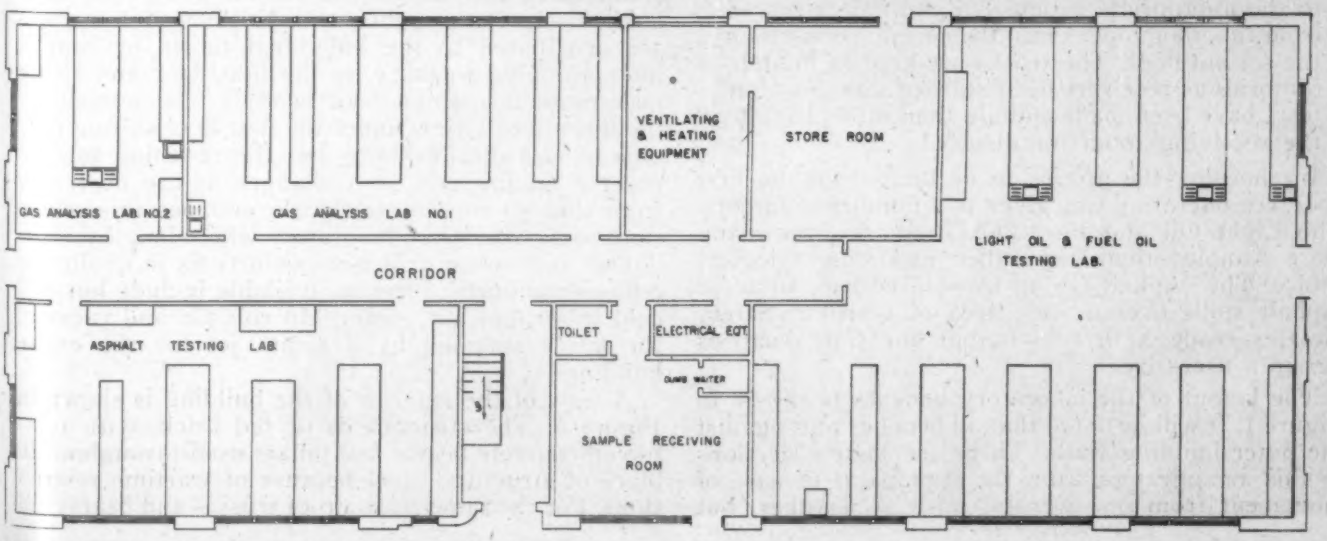


FIGURE 3
Vapor-Pressure table. Baths are set in cabinets with tops flush with working surface.

the new structure was proposed and did not enter into this problem.

One of the first considerations in laying out the new laboratory was the problem of sample distribution. In an average day somewhere around 1200 samples are received, calling for perhaps 3500 individual tests. After tests have been made the discarded samples must be picked up and sent either to the bottle cleaning rack or to storage. Perhaps the easiest solution to this problem would be a one-floor building. Since lack of suitable space for construction made necessary the two-story structure, however, the following arrangement was worked out:

1. The first floor was given over entirely to laboratories, storeroom, and sample-receiving room in order to minimize the number of samples that would have to be moved to the second floor, which houses all office space and remaining laboratories.
2. All samples are received in a central room, sorted and placed in small trucks for distribution to the appropriate group. A dumbwaiter served from this room opens into the central corridor on the second floor. The trucks are kept in the laboratories as receivers for discarded samples after tests have been made and are then rolled back to the receiving room for disposal.

In choosing the groups to be located on the first floor, consideration was given to a number of factors. The Light Oil and Fuel Oil Group receives many more samples than any other and was a logical choice. The Asphalt Group was placed here to avoid asphalt spills over a wide area of corridor. Safety dictates made a first-floor spot for Gas Analysis Group a necessity.

The layout of the laboratory benches is shown in Figure 1. It will be noted that all benches butt against the outer building walls. There are some objections to this arrangement from the standpoint of ease of movement from one working aisle to another, but the very nature of routine work makes it unnecessary for the majority of the testers to move about to any extent. The saving in space therefore overbalances the slight convenience of having passageways at both ends of the tables. Emergency exits from any working aisle are provided, however, for use in case of fire.

Every petroleum chemist knows that the tests made today may be replaced by others tomorrow and that new ones are being added constantly. In order to provide a maximum of flexibility, therefore, special benches were avoided as far as possible. There were a few instances, however, of equipment requiring tables lower than the standard 36-inch type and other cases where convenience and the prospect of permanence permitted the design of special units. Some of these special units are shown in the accompanying photographs. A general view of one of the larger laboratories is shown in Figure 2.

All service lines were brought into the building from the rear, through the storeroom and at a level about three feet below the second floor. The lines hold this level throughout the building and services are distributed to the individual tables by branch lines dropping to those on the first floor and rising underneath the second floor benches. The location of the lines in full view under the first floor ceiling may appear as a disadvantage, but the resulting ease of making repairs and such changes as are necessary from time to time more than overcomes this objection, particularly in a laboratory where lengthy shutdowns may cause expensive reductions in quality of refinery products. Services available include hot and cold water, gas, air, steam, 110 volt a.c. and vacuum, the latter supplied by a steam jet for the entire building.

A view of the exterior of the building is shown in Figure 5. The structure is of red brick, with reinforced concrete beams and pillars used throughout in place of structural steel because of wartime restrictions. For the same reason roof trusses and beams are

FIGURE 4
Viscosity table. Note switches in apron rail controlling electric timers on reagent shelf.

of heavy timber. Inside walls are of tile, plastered and painted, with the corridors finished to a height of five feet in a decorative glazed tile. The ample windows are of heat-absorbent blue glass, designed to reduce radiant heat from the sun. All hood blowers are located in the attic and exhaust through three large vents in the roof. A blower located on the first floor, supplies heated and filtered air to replace that exhausted by the hoods during the colder months.

No attempt is made here to state that the ideal refinery laboratory has been evolved, since every such laboratory must be designed to meet the needs peculiar to the refinery which it serves. The building does, however, meet the needs of the Baton Rouge organization and is a source of considerable pride and satisfaction to the laboratory staff.

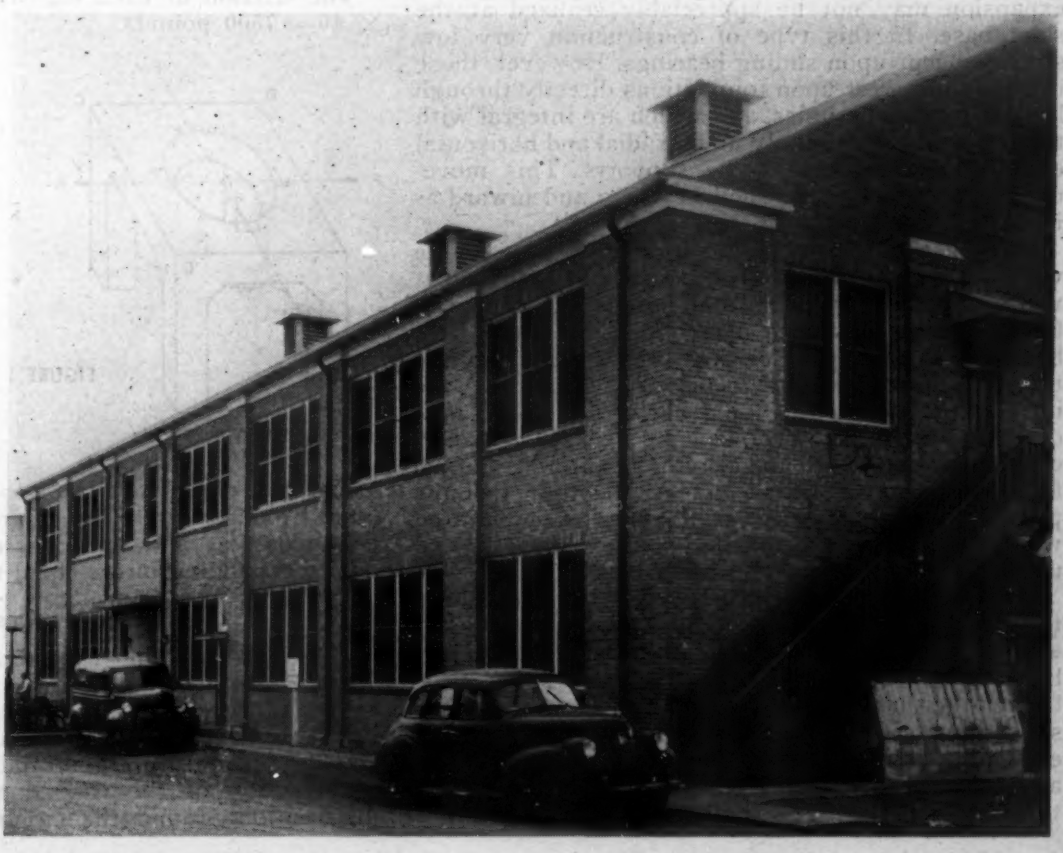


FIGURE 5
This view of the laboratory is no evidence that conditions restricted choice of materials.

Sliding Bearings For Hot Towers And Tanks

WESLEY H. BLANK
Consulting Engineer

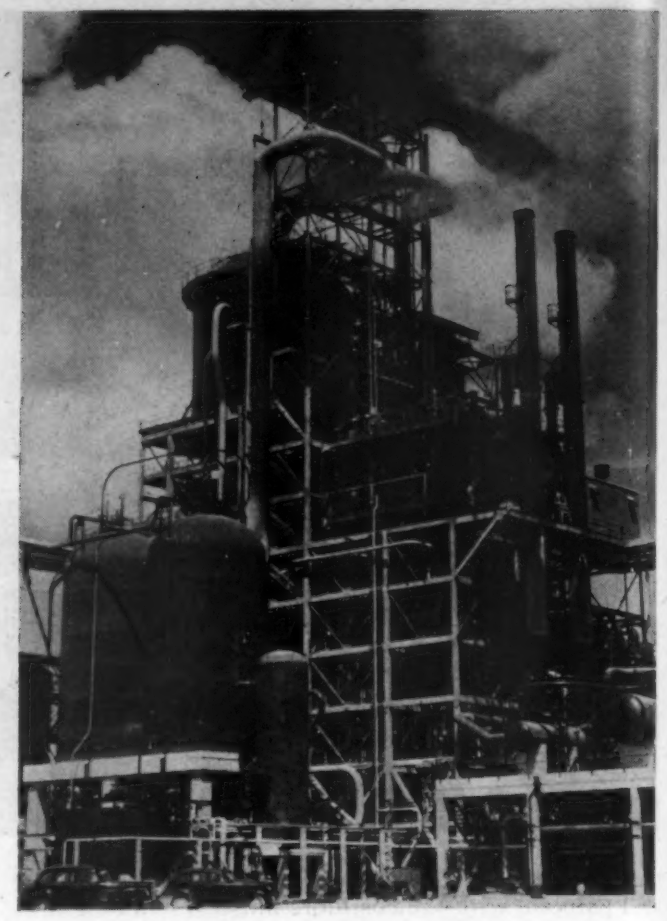
THE article in the PETROLEUM REFINER for February, 1944, by Samuel Garnett on the "Design of Foundations for Elevated Towers" was most ably explained and meets the common problem of structural engineers engaged on petroleum, rubber and chemical plants. There is, however, one phase not touched upon and that is "temperature stresses" due to hot towers.

General

Usually towers rest either upon lugs bracketed to the shell or upon a continuous stiffened flange ring, or may have an extension skirt of steel with a base ring. Where a skirt of some length with plenty of freedom for air circulation exists, the radial tower expansion may not be appreciably realized at the skirt base. In this type of construction very low stresses occur upon sliding bearings. However, those towers which rest upon foundations directly through lugs or base ring angles, and which are integral with the hot shell are definitely under radial and horizontal expansion movement at the supports. This movement is outward as the shell heats up and inward as it again cools down.

The base ring when bolted directly to concrete would bear upon a hard grout surface. No movement will occur until after the "steel on smooth concrete" friction factor has been overcome. This factor will be possibly 20 percent of the vertical weight of the tower. If sole plates cut to match the base ring are introduced, the friction could be reduced to a range of 13 to 15 percent for "steel on steel." These percentages are still high and also the resulting frictional force of resistance which equals the product of the particular frictional coefficient times the operating weight of tower—as distributed upon each lug or uniformly if such be the case. ($F = k \times W$.)

Up to the released point of frictional resistance the shell of the tower undergoes temperature stresses equal to the restraint against free expansion at the base. After the resistance of the base supports is broken the shell is free to expand and the entire tower slides imperceptibly over the supports. There always exists the frictional resistance which creates direct and bending stresses in the framework supporting the lugs or base ring of the hot tower.



Example

Let us assume a certain evaporator weighing 200,000 pounds operating weight and which has a differential of 700 degrees temperature. The shell is supported equally at 4 lug points. (Steel on steel).

The friction at each lug will equal $\frac{1}{4} \times 200{,}000 \times .15 = 7500$ pounds.

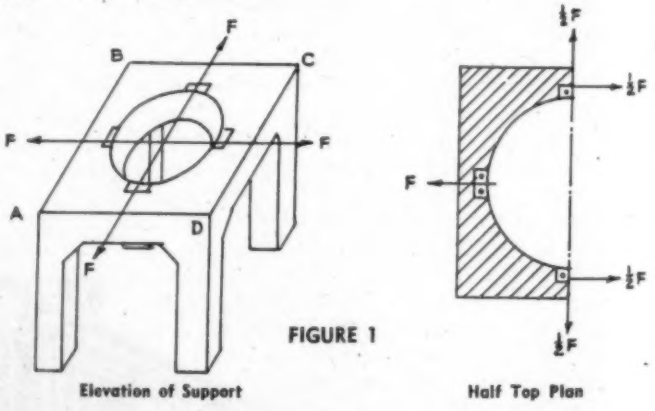


FIGURE 1

The top plane ABCD of the support will be required to take direct stress and shear. In case of a mass concrete mat, the concrete is in ring tension due to expanding forces equal to 3750 pounds.

Houdry Cases

All hot towers and cases do not resolve their reactions and frictional forces as simply as in the example preceding. Let us consider the "Houdry Catalytic Cracking Case" which may operate under a 800° temperature differential. Because the internal construction of the case does not produce equal distribution around the circumference of the shell

and hence develops different reactions on each pair of diametrically opposite supports, the frictional resistance at each pair of supporting points will differ. The load distribution, shown in Figure 2, depends on the orientation of the case with regard to the axis of the case structure. The figures given are percentages of total case weight on each support.

The framework indicated is the usual adopted construction for supporting these heavy cases.

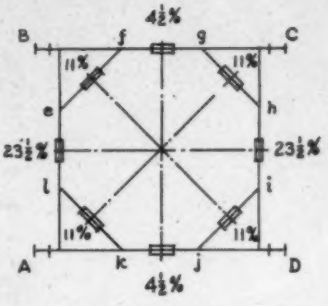


FIGURE 2

Short Beams ef, gh, ij, lk, are under horizontal bending and direct stress.

Main Beams ab, bc, cd, da, are likewise similarly stressed due to frictional forces of different magnitudes. As this entire frame is very rigidly connected and totally encased in concrete it becomes a rigid frame with end joint moments.

Details of Bearings

Cases or heavy towers supported at lug points or ring flanges bear on castings bolted to the substructure frame. The lug or ring is ribbed back to the case shell to resist bending. The lug does not, however, bear directly upon the casting, but a special low friction bearing plate is sandwiched in between. Such a plate is of bronze with entire surface covered with trepanned holes filled with graphite sticks and both faces greased with a graphite lubricant. The stick lubricant area reduces the metal contact surface and the coefficient of friction is claimed to be as low as 5 percent, but 7 percent is the usual design factor.

To direct the slide radially, the plate has a raised running bar which slides in the keyway grooved

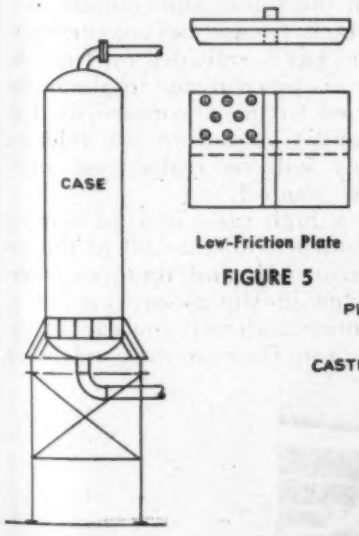


FIGURE 3

Low-Friction Plate
FIGURE 5

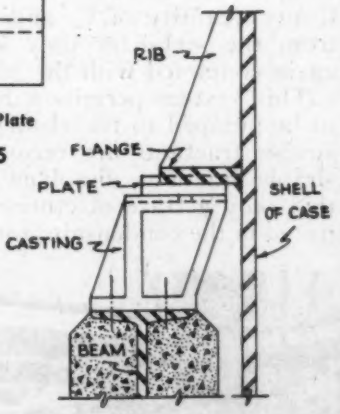


FIGURE 4

radially in the contact face of the shell supporting lug; and at the bottom of the plate to form a lock with the casting, the running bar on the plate sets in a groove planed in the thick top plate of the casting at right angles to the upper keyway.

Of course great accuracy is necessary in placing the castings on the supporting frame, so that they are dead level, truly aligned and exactly located.

Figures 3, 4, and 5 show generally, the case upon a steel frame support; details at the lug support; and the special low-friction sliding plate. One successful make of plate is called "Lubrite."

Horizontal Tanks

Horizontal tanks under high temperature, especially the salt storage tanks in Houdry units, have much expansion both longitudinally and diametrically. These tanks rest upon their lugs and slide on "Lubrite plates" keyed to castings. The direction

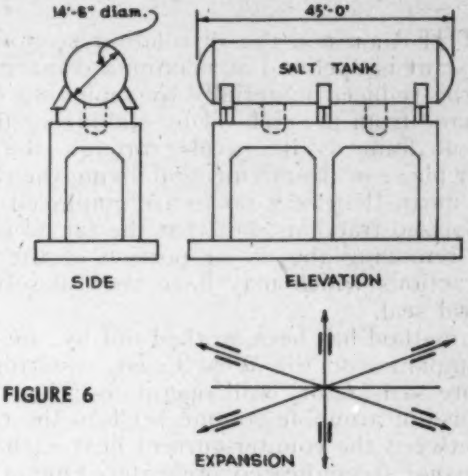


FIGURE 6

of keying is determined by running a line from the center point of fixity to the bearings. The stresses set up are all outward or all inward with diametrically opposite groups balancing. Tension or compression is set up in the top frame members.

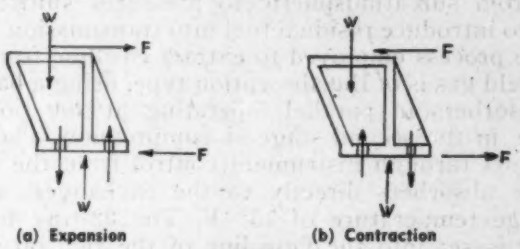


FIGURE 7

One last structural point of importance is the moment in the castings carried down to the supports of these castings due to (a) Horizontal friction force at top surface, and (b) Eccentric vertical forces on offset castings required to get clearances from the shell to allow for shell insulation and fireproofing of the steel supports with concrete. (See Figure 7.)

Final

No attempt has been made to cover all forms of temperature movement of towers and tanks at their supports. Neither has consideration been given to the effect of large pipes connected to the ends and sides of long hot towers. Where stairs and platforms are used in conjunction with towers for servicing manholes to bubble trays or for access to pipes and valves, careful thought to adequate vertical sliding details must be given at points where the tower and stairwell shaftway tie in together.

In the more recent fluid cat cracker type of 100-octane plants the big unit has several ingenious methods of taking horizontal and vertical temperature movements. It is sufficient to state that no support can be considered fully investigated for safety until all hot equipment has had its temperature expansion effects traced and duly allowed for.

Removing Undesirable Fractions From Rich Oil Lessens Load on Still And Atmospheric Condensers

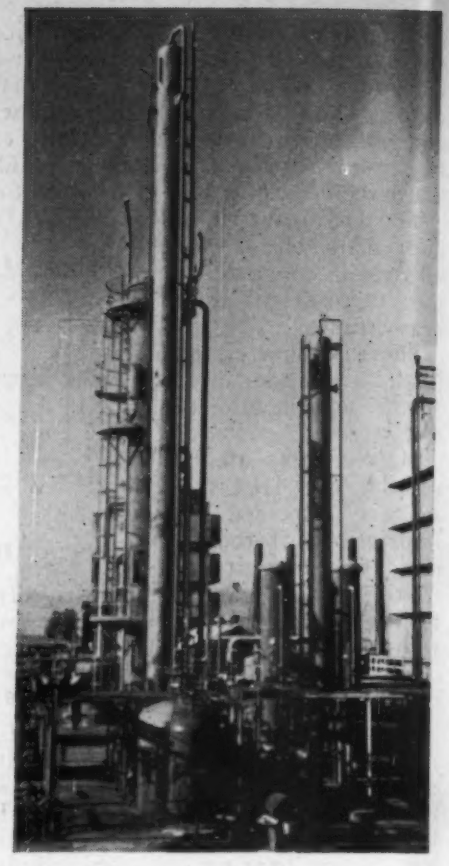
WHETHER or not the distillation section of a gasoline plant is operated at maximum capacity, the load can be reduced materially by removing ethane and methane from the rich oil by stabilizing the absorption medium as it travels through the heat-exchanger phase of the circuit. Stabilizing the rich oil does not mean that vent tanks are employed to release vaporized fractions, but that the fat oil is fractionated, removing the major portion of the undesirable fractions which may have been dissolved in the mineral seal.

Such a method has been worked out by one of the larger companies on the West Coast, resulting in a much more satisfactory still operation. The method involves use of a bubble column set into the rich-oil stream between the counter-current heat exchangers and the usual steam-heated preheater. Operation of this tower requires no additional pumps, nor heat input other than the normal heating of the rich oil as it flows through the shell-and-tube heat exchangers.

The gasoline plant in which this process has been installed is equipped with facilities for handling the gas from sub-atmospheric to pressures sufficiently high to introduce residual fuel into transmission lines.

The process employed to extract gasoline from the rich field gas is of the absorption type, using a battery of absorbers in parallel, operating at 200 pounds, gauge, in the second stage of compression. The rich oil vents through instrument control from the bases of the absorbers directly to the exchangers at an average temperature of 75° F. The 22-tray bubble tower is set into the flow line of the rich oil so as to receive it before it enters the preheater, so that ethane and methane will flash off as they would normally do as the oil entered a vent tank. With vent-tank operation, all of the vapors thus released would flow directly to the still. Obviously, some desirable fractions are released in the bubble column, but these are returned to the base of the column because of reflux applied to the top of the rich-oil stabilizer.

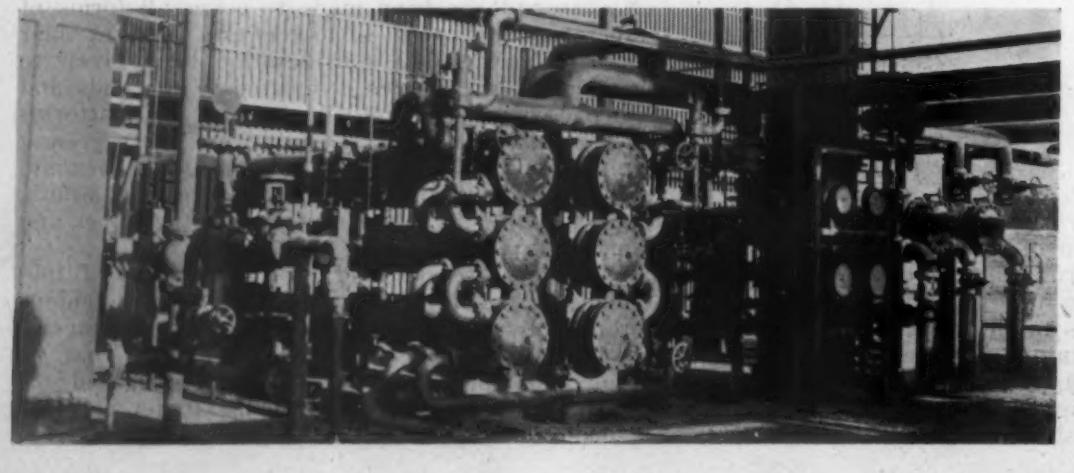
Since the rich oil from the base of the absorbers averages 75° F., and the rich oil after passing through the heat exchangers runs about 210° F., some of the cold rich oil operates to reabsorb the desirable fractions which normally would flow from the top of the column. Instruments on the control board near the rich-oil fractionator record operating conditions and allow the required quantity of cold rich oil from the absorbers to pass to the reflux nozzle of the stabilizer, to control the composition of the vapors which are released from the top of the column.



Rich-oil stabilizer unit shown to right of the plant towers.

As all of the gas which cannot be converted to natural gasoline or liquid gas is salvaged for fuel, the rich-oil-stabilizer discard is piped to the intake of the compressors and returned to the absorbers so that, if any quantity of C_3 and C_4 fractions are released from the stabilizer they will be reabsorbed when again contacted with the lean oil.

This system permits a high ratio of cold lean oil to be pumped to the absorbers so that all of the desirable fractions are recovered, and removes undesirable fractions dissolved in the absorption oil so that only a trace of ethane and methane can be detected in the condensate from the gasoline condensers.



Bank of shell-and-tube heat exchangers (in center) with two-inch piping at the base of absorbers (extreme left) which handle split stream of cold rich oil to stabilizer for rich-oil fractionation. Instruments shown are for control of this operation.

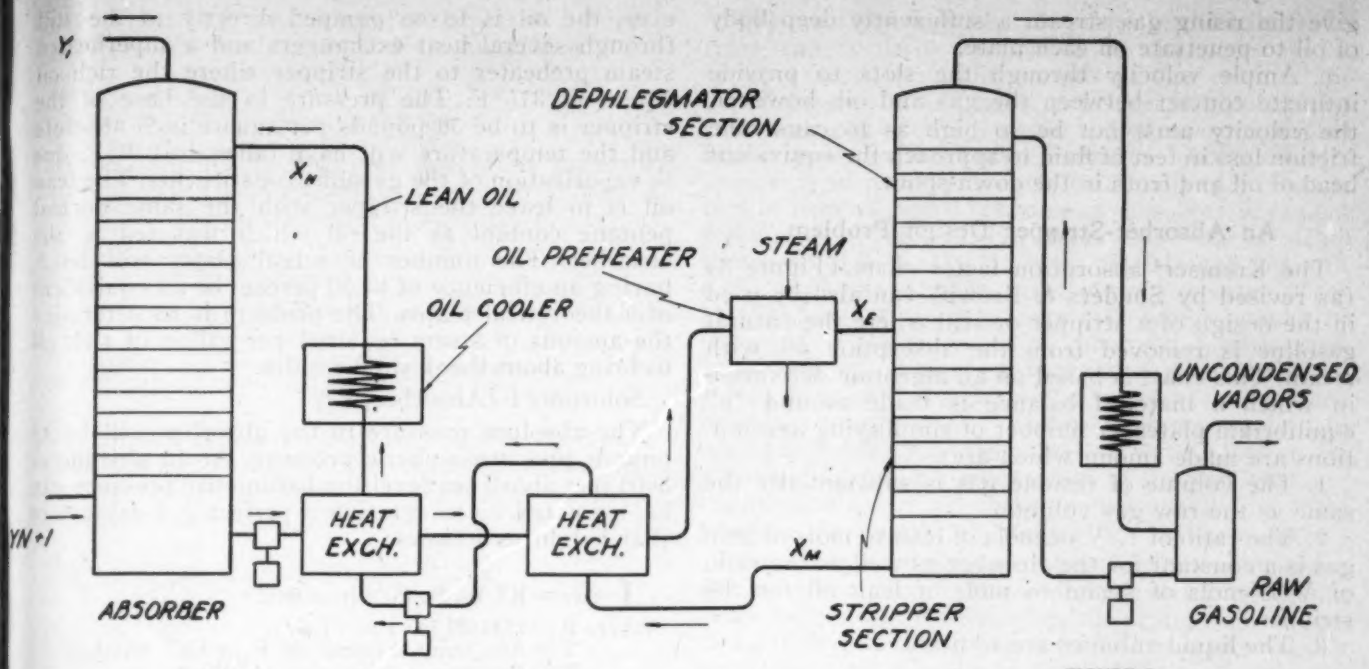


FIGURE 1
Conventional oil absorption and distillation unit.

Application of Unit Operations to

Fractionation and Other Vaporization Processes

PART 14

Application of the Kremser Method to the Design of Oil Absorbers

R. L. HUNTINGTON, University of Oklahoma

THE conventional oil absorber is a vertical bubble-plate tower in which the gasoline constituents are extracted from the gas stream by a descending counter-current flow of oil. Although the combination of trays, caps and downspouts has come into high favor, recent improvements in packing rings indicates that this form of baffling will regain at least part of its former standing as a means of bringing about intimate contact between gas and its absorbing medium. Perforated plates offer considerable promise due to certain recent improvements in their design.

The Bubble Plate Tower

The two principal factors to be considered in the design of the bubble plate tower are:

1. Provision of ample flow capacity for the oil and gas streams so as to prevent liquid hold up and entrainment.[1, 5, 6, 7]

2. A fairly close approach toward equilibrium between the gas and oil on each bubble plate.

To take care of factor No. 1 calls for:

a. Adequate down-spouts wherein the entrained vapor can free itself from the oil froth which is formed as the oil flows across the bubble caps.

b. Liquid seals at the base of the down-spout to prevent the flow of gas upward through the down-spout.

c. A tray spacing of 20 inches or more, generally 24 inches, between successive plates, in order to reduce entrainment or the mechanical carrying of liquid droplets upward from plate to plate.[1, 5, 7]

Factor No. 2 requires the following considerations:

a. Placement of bubble-caps in staggered rows so as to reduce the tendency for the oil to channel across the plate.

b. Proper height for the overflow weir in order to

give the rising gas stream a sufficiently deep body of oil to penetrate on each plate.

c. Ample velocity through the slots to provide intimate contact between the gas and oil, however, the velocity must not be so high as to cause the friction loss in feet of fluid to approach the equivalent head of oil and froth in the down-spout.

An Absorber-Stripper Design Problem

The Kremser[4] absorption factor chart (Figure 3) (as revised by Souders & Brown) can also be used in the design of a stripper or still where the natural gasoline is removed from the absorption oil with steam. This chart is based on an algebraic derivation in which a material balance is made around "n" equilibrium plates. A number of simplifying assumptions are made among which are:

1. The volume of residue gas is substantially the same as the raw gas volume.
2. The ratio of L/V or mols of lean to mols of lean gas is a constant for the absorber as well as the ratio of V/L mols of steam to mols of lean oil for the stripper.
3. The liquid volumes are additive.

The Absorber

An absorber containing 24 actual plates of 66-2/3 percent efficiency is to process a rich gas from some flowing oil wells. Ninety-five percent of the normal pentane in the raw gas is to be absorbed. The absorption oil has a specific gravity of 0.8 and a molecular weight of 180. Temperature of absorber = 90°F. Gauge pr.=40 lb. Altitude above sea level=3000 feet. Analysis of the rich gas is as follows:

Component	(% by vol.)
CH_4	= 82
C_2H_6	= 5
C_3H_8	= 3
Iso C_4H_{10}	= 1
N C_4H_{10}	= 3
Iso C_5H_{12}	= 1
N C_5H_{12} +	= 5

The dry oil being fed to the top of the absorber has a vapor pressure of 90°F. of 2.2 millimeters of mercury due to the presence of a little normal pentane remaining in the oil.

1. Calculate the gals. of lean oil/1000 std. cu. ft. dry gas.
2. Calculate the composition of the dry gas.
3. Calculate the gals. of lean oil/1000 std. cu. ft. rich gas.

The Stripper

The rich oil from the absorber is sometimes flashed into a low-pressure vent tank so as to cause a large percentage of the dissolved methane to be released thereby reducing the load of non-condensable gases on the still and condenser. In this case, however, the oil is to be pumped directly to the still through several heat exchangers and a superheated steam preheater to the stripper where the rich oil enters at 375°F. The pressure in the base of the stripper is to be 50 pounds per square inch absolute and the temperature will have fallen to 350°F. due to vaporization of the gasoline constituents. The lean oil is to leave the stripper with the same normal pentane content as the oil which was fed to the absorber. The number of actual plates will be 8, having an efficiency of 62.50 percent or an equivalent of 5 theoretical plates. The problem is to determine the amount of steam required per gallon of rich oil to bring about the desired results.

Solution: I (Absorber)

The absolute pressure in the absorber will be 40 pounds plus atmospheric pressure. At an altitude of 3000 feet above sea level the barometric pressure can be estimated by integrating a perfect gas column of that height as follows:

$$\int Pdv = RT \ln_e P_1/P_2 = \text{ft. of fluid}$$

Where R = 1544/29 for 1 lb. of air
T = Abs. temp. Assume 60° F. or 520° Absolute
P_1 = Pressure at sea level = 14.7 lbs./sq. in.
P_2 = Pressure at 3000 ft. elevation

Substituting into the integrated form:

$$\frac{1544}{29} \times 520 \times \ln_e \frac{14.7}{P_2} = 3000$$

P_2 = 13.05 lbs./sq. in. absolute at 3000 feet elevation

Absorber Calculations
(See definition of terms below)

Comp.	Mol. Frac.	Equilibrium Vaporization K = y/x	Vapor Pressure p	p/π	Absorption Factor $A = \frac{L}{vk}$	$\frac{y_{n+1}-y_1}{y_{n+1}-y_0}$	$\frac{y_{n+1}-y_1}{y_{n+1}}$	Cu. Ft. Absorbed Per 1000 Cu. Ft. of Raw Gas	Cu. Ft. of Residue Gas Per 1000 Cu. Ft. of Raw Gas
CH_4	.82	70	7800	143.5	0.00413	0.00413	0.00413	3.40	816.60
C_2H_6	.05	10	735	13.93	0.0289	0.0289	0.00289	1.45	48.55
C_3H_8	.03	2.7	168	3.17	0.1070	0.1070	0.1070	3.21	26.79
I C_4H_{10}	.01	1.15	67	1.26	0.2515	0.2515	0.2515	2.51	7.49
N C_4H_{10}	.03	0.86	46	0.87	0.3360	0.3360	0.3360	10.10	19.90
I C_5H_{12}	.01	0.36	17	0.32	0.8030	0.8030	0.8030	8.03	1.97
N C_5H_{12}+	.05	0.27	13	0.245	1.070	0.965	0.95	47.50	2.50
Total								72.20	923.80

Total Pressure (π) = 53 lbs./sq. in. abs.
Theoretical plates = 24 × 2/3 = 16

$$px_{c5} = \frac{2.2}{760/14.7} = \frac{2.2}{51.7}$$

$$\pi Y_o = px_{c5} \qquad Y_o = \frac{2.2}{51.7(53)} = .0008$$

Evaluation of theoretical fraction to be absorbed:

$$\frac{y_{n+1}-y_1}{y_{n+1}-y_o} = \frac{.05-.0025}{.05-.0008} = 0.965 \text{ for N } C_5H_{12+}$$

$$\frac{y_{n+1}-y_1}{y_{n+1}} = 0.95 \text{ (Actual fraction of N } C_5 \text{ to be absorbed)}$$

By referring to the absorption factor chart (Figure 3) the theoretical fraction (0.965) is read across horizontally to the 16 plate line and then downward to the absorption factor

$$\left(A = \frac{L}{VK}\right) = 1.07$$

From this relationship,

$$L/V = KA = 0.25 \times 1.07 = .289$$

This relationship L/V is a constant for this particular condition, therefore the absorption factors

for the other hydrocarbons can be obtained by dividing L/V=.289 by the respective values of K.

$$L/V = \frac{\text{mols lean oil}}{\text{mols of dry gas}}$$

This relationship is not used by plant operators therefore it must be converted over into gallons of lean oil per thousand standard cubic feet of dry gas.

$$\frac{\left(\frac{.289 \text{ mols} \times 180 \text{ (lbs./mol.)}}{0.8 \times 8.33 \text{ lbs./gal.}}\right)}{380 \text{ (std. cu. ft./lb. mol.)}} = 8.25 \text{ gals./380 std. cu. ft. of gas}$$

$$\text{or } \frac{1000}{380} \times 8.25 \text{ gals.} = \frac{21.7 \text{ gals. of lean oil}}{1000 \text{ std. cu. ft. of dry gas}}$$

The gallons of lean oil per thousand standard cubic feet of rich gas will be smaller than the ratio of lean oil to lean gas by the ratio of the lean gas volume to that of the rich gas. This ratio will therefore be

$$21.7 \times .9238 = \frac{20.02 \text{ gals. lean oil}}{1000 \text{ std. cu. ft. rich gas}}$$

The Stripper

The still is a bubble-plate tower (Figure 1) consisting of two sections. The upper half is the dephlegmator and the lower, the stripping section. The function of the dephlegmator is that of knocking back the absorption oil which is vaporized in the stripping section, through the refluxing of raw gasoline over the top of the tower. The stripper reverses the operation of the absorber in that it drives out the gasoline and other lighter hydrocarbons which are recovered in the absorber from the raw gas. Live steam generally is used as a stripping agent as it reduces the partial pressure of the hydrocarbons in the lower part of the still; furthermore the steam condenses readily in the upper portion of the dephlegmator and also in the condenser thereby bringing the partial pressure of the hydrocarbons back to a higher level for ready condensation.

The partial pressure of the steam in the still varies from substantially 50 pounds in the base of the stripper section to 29.4 pounds at the base of the dephlegmator. The partial pressure is obtained by considering the ratio of steam to hydrocarbon vapors at any point in the tower. From the above calculations it is seen that there are 0.405 mols of steam per mol of lean oil and 0.221 mols of dissolved gases per 0.779 mols of lean oil. For every .405 mols of steam there would be 0.221/.779 mols of dissolved gases or 0.283. The volume of mol fraction of the vapor space at the base of the dephlegmator which would be occupied by steam, would be .405/(.405+.283)=.588. From the standpoint of vaporization, the rich oil would flash off its vapors to the same extent provided no steam were used but the total pressure on the still would have been lowered to 50—29.4=20.6 lbs./sq. in. absolute. Effective condensation of the raw gasoline vapors could not be obtained at such a low total pressure, by means of atmospheric cooling water.

About 25 years ago, a few natural-gasoline-plant operators considered the use of some stripping agents other than steam for denuding absorption oil. It was thought that dry residue gas might be as effective as steam and that it could be obtained at a much lower price. The folly of such an idea was soon shown up when it was found that the overhead vapors were non-condensable and that the gas had been brought back to substantially the same composition as it was when it had first flowed into the absorber.

A combustion stripper and dephlegmator operating in series is shown in Figure 2. Some companies claim that more economical operation can be obtained by refluxing water over the dephlegmator thereby creating an internal gasoline reflux.

Variations in Absorber Operations

With changing markets and variations in price schedules for different products, the natural gasoline manufacturer must keep in step by increasing the efficiency of the absorption system when prices are high. This result can be accomplished either by lowering the temperature of the absorption oil and raw gas or by raising the pressure on the tower, e.i., within the pressure range from atmosphere up to the inversion point of the retrograde region. Above this point the opposite effects may be experienced.

Stripper Calculations

	Mols.	Rich Oil Mol. Frac.	Stripping Factor $S = \frac{VK}{L}$	Ratio of Mols. Stream / Mols. Lean Oil	K 350° F. 50	Actual Frac. Stripped $\left(\frac{x_s - x_n}{x_n}\right)$	Theo. Fraction Stripped $\left(\frac{x_s - x_n}{x_s - x_o}\right)$	Mols. Stripped Out
CH_4	.004	.0116	243.00	0.405	600	1.00	1.00	.004
C_2H_6	.0009	.0026	10.12	0.405	25	1.00	1.00	.0009
C_3H_8	.0032	.0093	5.06	0.405	13	1.00	1.00	.0032
I C_4H_{10}	.0025	.0073	3.24	0.405	8	1.00	1.00	.0025
N C_4H_{10}	.0101	.0294	2.83	0.405	7	1.00	1.00	.0101
I C_5H_{12}	.0080	.0234	2.03	0.405	5	.982	.982	.0078
N C_5H_{12}	.0474	.1380	1.86	0.405	4.6	.976	.976	.0462
Lean Oil	.2670	.7790	.31	0.405	0.76	.31	.31	.0828

$$x_n = \frac{2.2}{13.1 \times 51.7} = .00325 \text{ (mol. fraction of N pentane in lean oil)}$$

$$\frac{x_s - x_n}{x_s} = \frac{0.1380 - .00325}{0.1380} = 0.976 \text{ (Actual fraction of N pentane to be stripped out of rich oil)}$$

Stripping factor (S) for 0.976 and 5 theoretical plates = 1.86

$$\frac{V}{L} = \frac{S}{K} = \frac{1.86}{4.6} = 0.405 \text{ mols. of steam/mol. of lean oil}$$

$$\frac{\text{lbs. of steam}}{\text{Gals. Lean Oil}} = \frac{.405 \times 18}{180} = .2705 = \frac{V}{L}$$

$$(8.33 \times .8)$$

Where 18 = lbs. of water per lb. mol.
180 = lbs. per mol. wt. of oil
$8.33 \times .8$ = wt. of gallon of oil

Effect of Pressure Changes

A marked reduction of oil circulation can be realized by increasing the pressure in the absorber. For example (See Figure 4) the oil circulation in gallons

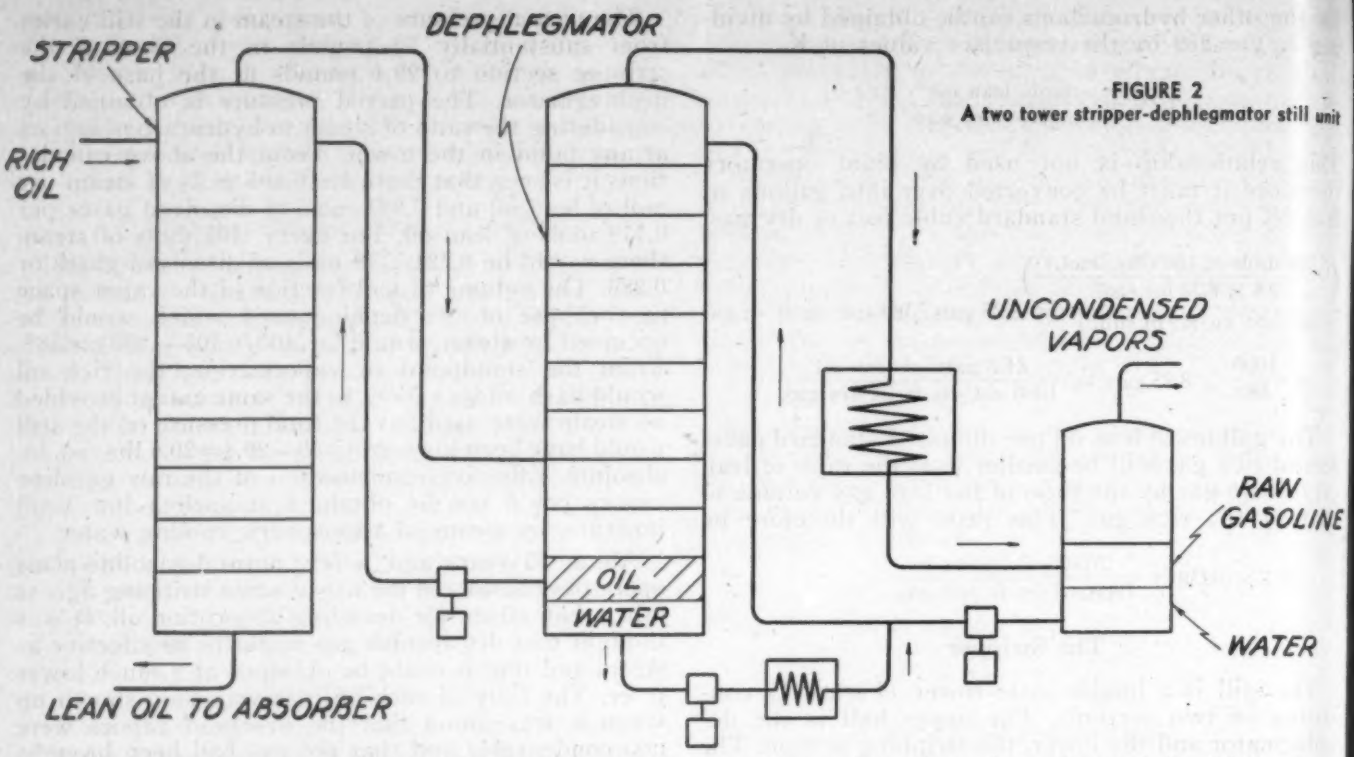


FIGURE 2
A two tower stripper-dephlegmator still unit

per 1000 standard cubic feet of residue gas must be increased from 6 gallons up to 65 gallons if the pressure is lowered from 200 pounds down to 20 pounds per square inch absolute. Gasoline plants operate as a rule with 40 to 50 pounds gauge pressure on the absorbers unless there is a demand for high pressure such as a remote market for the dry gas as fuel or for gas lifting of oil wells in the field. In other words the additional cost of compressing gas to a high level offsets by far the saving in oil circulation

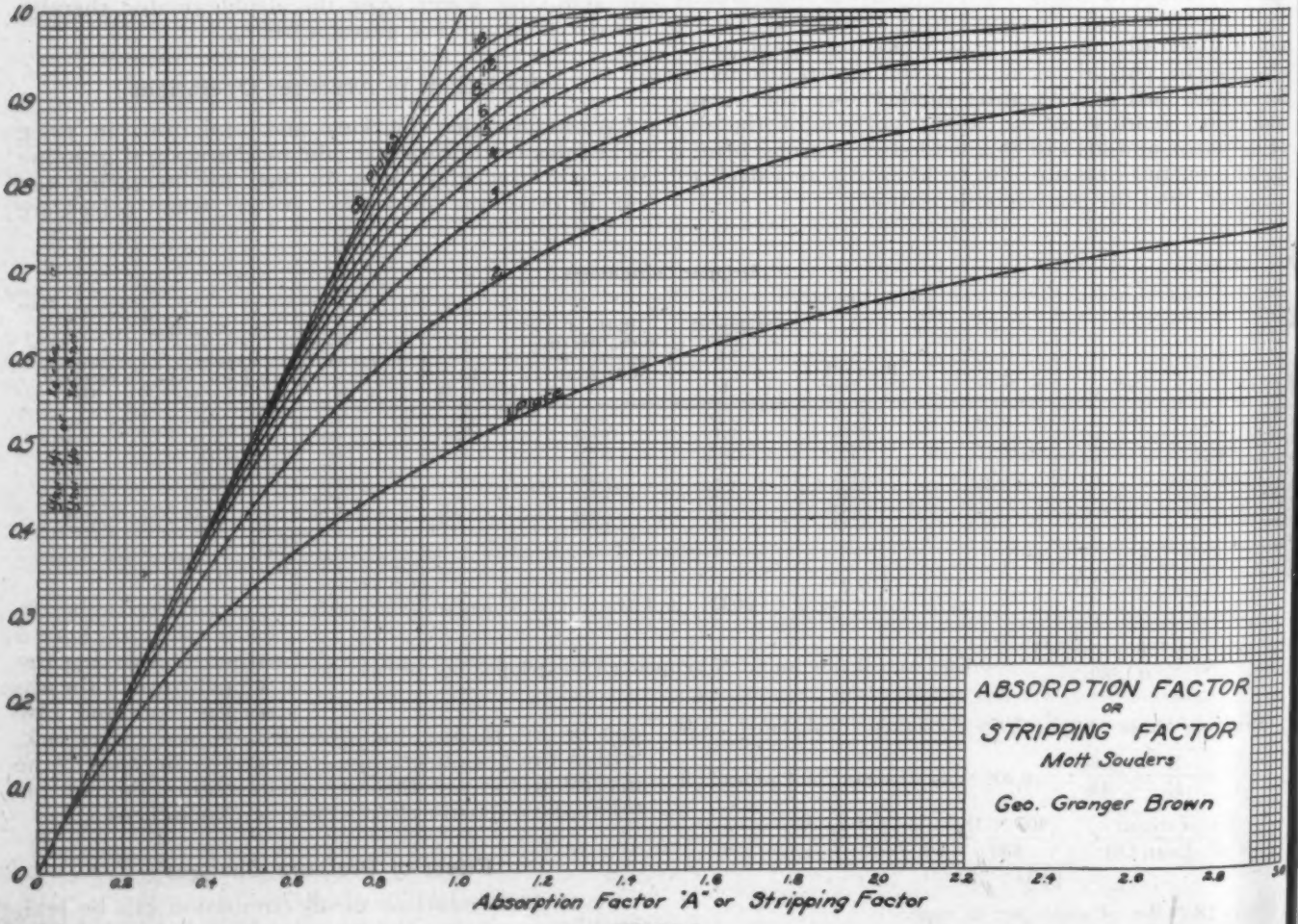


FIGURE 3
Absorption factor chart.

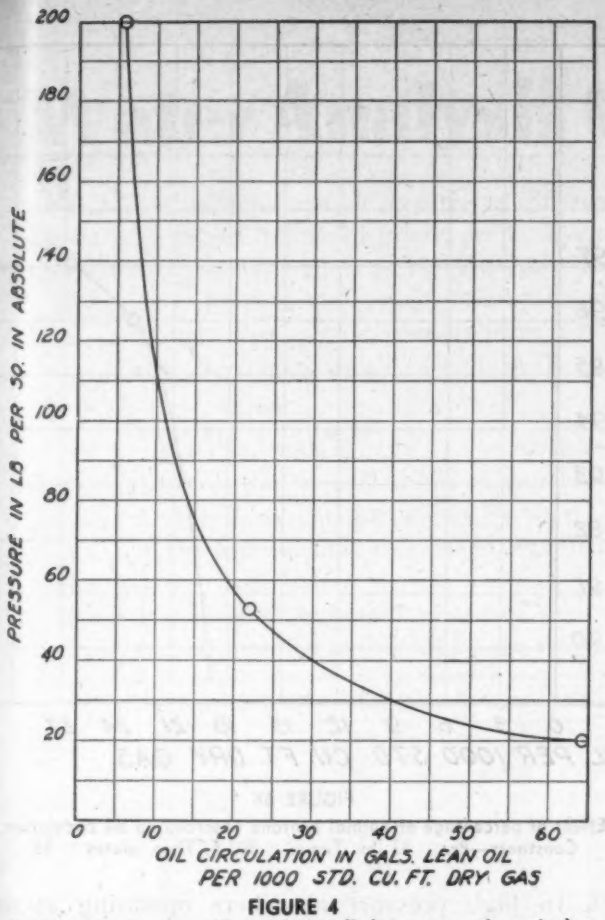


FIGURE 4
Effect of pressure on oil circulation (below retrograde region). Constants—Temp. = 90° F. Theo. plates = 16.

costs such as steam for stripping and for pumping the oil.

The reduction in the temperature of the absorption oil is often the most economical method of increasing the efficiency of an absorber. The oil should be cooled to within 10°F. of the circulating water and the water within 5 to 10°F. of the wet-bulb temperature. For further refrigeration it is customary to use propane or butane as a means of heat removal.[3] In figure 5 it is shown that an oil circulation of 12 gallons per thousand cubic feet of lean gas at 60°F. is just as effective as 30 gallons per thousand cubic feet at 110°F.

Number of Theoretical Plates

By increasing the number of bubble plates in the tower, the oil circulation can be materially reduced. For example, in Figure 6A, it is easily seen that whereas 41 gallons of oil per thousand standard cubic feet of dry gas are required for a 4-plate tower, only 22 gallons are needed for a 16-theoretical-plate absorber. The most economical tower to build will, of course, depend upon the relative value of the gasoline to be marketed and the cost of operating the plant. Probably some intermediate point such as 8 to 12 theoretical plates may prove to be the most economical tower to select, however, the trend recently has been toward the installation of more plates in each absorber. This tendency may be due to the increasing demand for propane and the butanes.

Percentage Normal Pentane Recovered

Many absorbers are designed on the basis of the recovery of a certain percentage of normal pentane. As higher percentages of the pentanes are desired more absorption oil must be circulated. This relation-

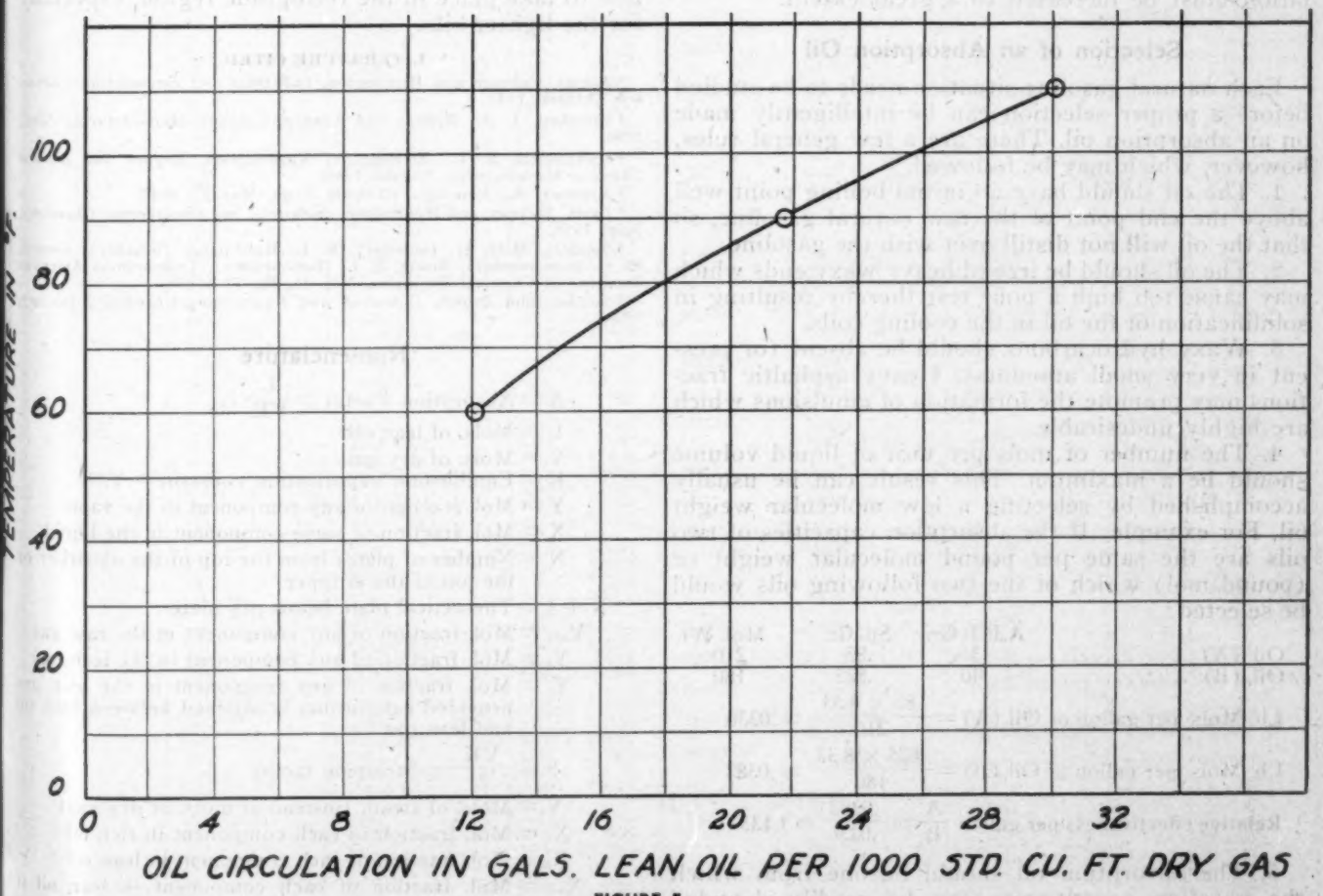


FIGURE 5
Effect of temperature on oil circulation. Constants—Pr. = 53 lbs. Theo. Plates = 16.

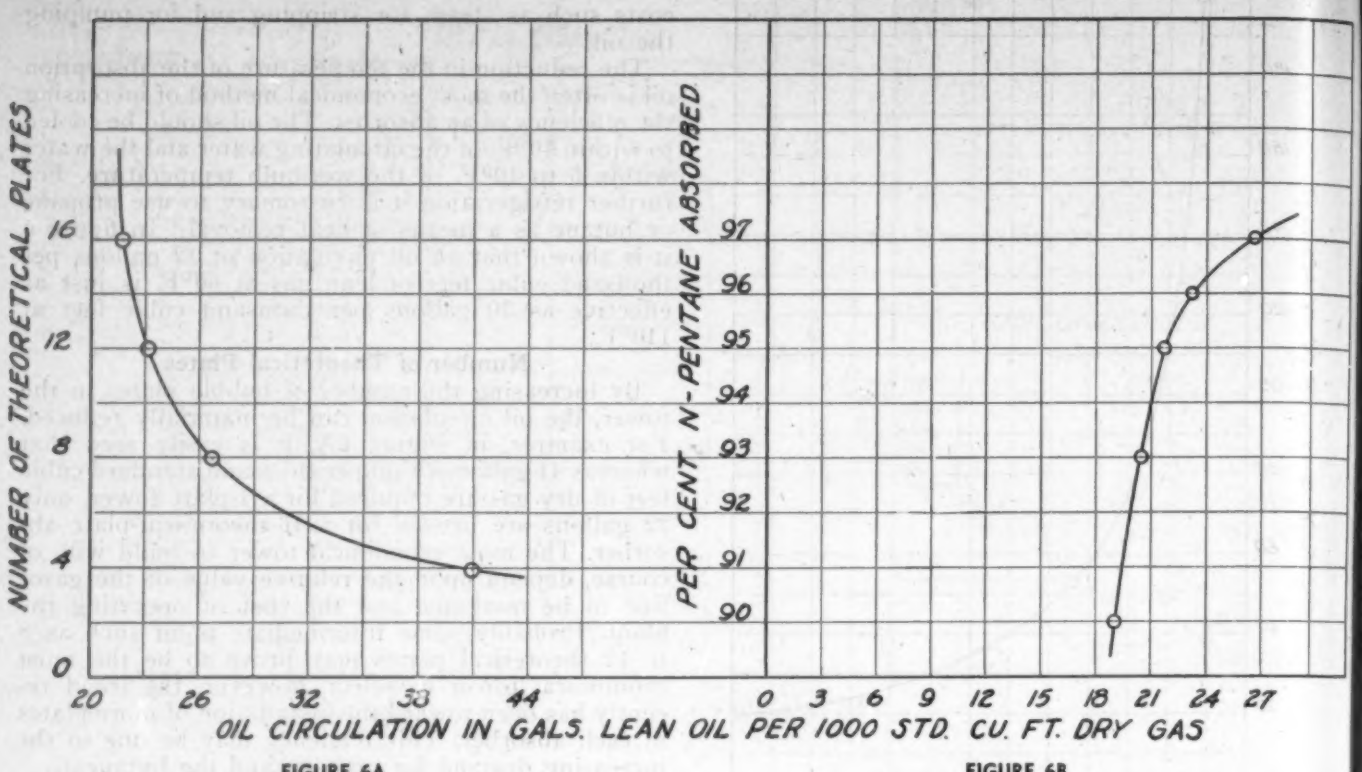


FIGURE 6A

Effect of number of theoretical plates on oil circulation. Constants—Pr. = 53 lbs. Temp. = 90° F.

FIGURE 6B

Effect of percentage of normal pentane absorbed on oil circulation. Constants—Pr. = 53 lbs. Temp. = 90° F. Theo. plates = 16.

ship is shown in Figure 6B. The curve brings out the fact that as the last small percentage of normal pentane is recovered from the raw gas, the oil circulation must be increased to a great extent.

Selection of an Absorption Oil

Each natural gasoline situation needs to be studied before a proper selection can be intelligently made on an absorption oil. There are a few general rules, however, which may be followed.

1. The oil should have an initial boiling point well above the end point of the raw natural gasoline, so that the oil will not distill over with the gasoline.

2. The oil should be free of heavy waxy ends which may cause too high a pour test thereby resulting in solidification of the oil in the cooling coils.

3. Waxy hydrocarbons should be absent (or present in very small amounts). Heavy asphaltic fractions may promote the formation of emulsions which are highly undesirable.

4. The number of mols per unit of liquid volume should be a maximum. This result can be usually accomplished by selecting a low molecular weight oil. For example: If the absorption capacities of two oils are the same per pound molecular weight or (pound mol) which of the two following oils would be selected?

	A.P.I. Gr.	Sp. Gr.	Mol. Wt.
Oil (A)	35	.85	210
Oil (B)	40	.825	180

$$\text{Lb. Mols. per gallon of Oil (A)} = \frac{.85 \times 8.33}{210} = .0336$$

$$\text{Lb. Mols. per gallon of Oil (B)} = \frac{.825 \times 8.33}{180} = .0382$$

$$\text{Relative effectiveness per gallon } \frac{A}{B} = \frac{.0382}{.0336} = 1.135$$

5. The absorption oil should be one from which the gasoline constituents can be readily denuded or stripped out in the still.

6. In high pressure absorbers operating at 600 pounds or more, higher molecular weight oils are recommended since there is a tendency for vaporization to take place in the retrograde region, especially for the lighter oils.

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[3] Huntington, R. L., Elements of Vaporization, *Refiner and Natural Gasoline Manufacturer*, August, 1940.

[4] Kremser, A., *National Petroleum News*, May 21, 1930.

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[6] Souders, Mott, Jr. (member), R. L. Huntington (member), Corneil, H. G. (non-member), Emert, F. L. (non-member), Transactions American Institute of Chemical Engineers, Vol. 34, Pg. 71 (1938).

[7] Souders and Brown, *Industrial and Engineering Chemistry*, January, 1934.

Nomenclature

$A = \text{Absorption Factor} = \frac{L}{VK}$

L = Mols. of lean oil

V = Mols. of dry gas

K = Equilibrium vaporization constant = Y/X

Y = Mol. fraction of any component in the vapor

X = Mol. fraction of same component in the liquid

N = Number of plates from the top of the absorber or the top of the stripper

$N+1$ = Theoretical plate below nth plate

Y_{n+1} = Mol. fraction of any component in the raw gas

Y_1 = Mol. fraction of any component in the lean gas

Y_o = Mol. fraction of any component in the lean gas provided equilibrium is attained between lean oil and lean gas

$S = \frac{VK}{L}$ = Stripping factor

V = Mols. of steam (instead of mols. of dry gas)

X_o = Mol. fraction of each component in rich oil

X_n = Mol. fraction of each component in lean oil

X_{n+1} = Mol. fraction of each component in lean oil if equilibrium is attained between oil and stripping medium. (For steam and oil $X_{n+1} = 0$)

Water Analysis Conversion Factors

WATER analyses can be reported in different ways, in the "ionic" form where the constituents are shown in parts per million or grains per U. S. gallon as Ca, Mg, HCO_3, etc.; or in the form of hypothetical combinations such as $Ca(HCO_3)_2$, NaCl, etc.

In refinery and natural-gasoline-plant operations it is often desired to make conversions from the ionic form to the hypothetical combination form, and vice versa. The following tabulation of factors covers many of the conversions usually sought in the plant. Multipliers for changing from p.p.m. to grs./U.S. gal. are:

Given	Wanted	Multiplier
Grains per U. S. Gallon	Parts per Million	17.138
Parts per Million	Grains per U. S. Gallon	0.583

The tables contain two columns of numbers; one titled "Factor", with the second titled "Reciprocal". Suppose a water analysis report shows Fe (iron) 2. grains/gal. and it is desired to figure how much Fe-(HCO_3) (iron bicarbonate) this would represent. The desired factor is 3.1851, so 3.1851×2 gives 6.37 grains/gal. iron bicorbonate.

If the analysis had been reported as 6.37 grains/gal. iron bicarbonate and iron alone (Fe) was desired, the 6.37 grains would be multiplied by the reciprocal 0.3140 to obtain 2.0 grains Fe.

	Given	Wanted	Factor	Reciprocal
Fe	Fe	$Fe(HCO_3)_2$	3.1851	0.3140
	Fe	$FeSO_4$	2.7203	0.3676
	Fe	Fe_2O_3	1.4298	0.6994
Al	Al	Al_2O_3	1.8899	0.5291
Mg	Mg	$Mg(HCO_3)_2$	6.0171	0.1662
	Mg	$MgCO_3$	3.4671	0.2884
	Mg	$Mg(OH)_2$	2.3987	0.4169
	Mg	$MgSO_4$	4.9500	0.2020
	Mg	$MgCl_2$	3.9158	0.2554
	Mg	$Mg(NO_3)_2$	6.0993	0.1640
	Mg	$Mg_3(PO_4)_2$	3.6049	0.2774
	Mg	$MgSiO_3$	4.1257	0.2424
	Mg	MgO	1.6579	0.6032
Ca	Ca	$Ca(HCO_3)_2$	4.0451	0.2472
	Ca	$CaCO_3$	2.4974	0.4004
	Ca	$Ca(OH)_2$	1.8489	0.5409
	Ca	$CaSO_4$	3.3974	0.2943
	Ca	$CaCl_2$	2.7698	0.3610
	Ca	$Ca(NO_3)_2$	4.0950	0.2442
	Ca	$Ca_3(PO_4)_2$	2.5810	0.3874
	Ca	$CaSiO_3$	2.8982	0.3450
	Ca	CaO	1.3992	0.7147
Na	Na	$NaHCO_3$	3.6529	0.2738
	Na	Na_2CO_3	2.3044	0.4340
	Na	NaOH	1.7396	0.5782
	Na	Na_2SO_4	3.0886	0.3238
	Na	NaCl	2.5417	0.3934
	Na	$NaNO_3$	3.5226	0.2839
	Na	Na_3PO_4	2.3774	0.4206
	Na	Na_2SiO_3	2.6537	0.3768
HCO_3	HCO_3	$CaCO_3$	1.640	0.6098
	HCO_3	$Ca(HCO_3)_2$	1.3284	0.7528
	HCO_3	$Mg(HCO_3)_2$	1.1993	0.8338
	HCO_3	Na_2CO_3	1.7371	0.5757
	HCO_3	$NaHCO_3$	1.3770	0.7262
	HCO_3	$Fe(HCO_3)_2$	1.4576	0.6861
	HCO_3	Co_3	0.9835	1.0168
CO_2	CO_2	$CaCO_3$	2.2743	0.4397
	CO_2	$Ca(HCO_3)_2$	1.8419	0.5429
	CO_2	$MgCO_3$	1.9164	0.5218
	CO_2	$Mg(HCO_3)_2$	1.6629	0.6014
	CO_2	Na_2CO_3	2.4090	0.4151
	CO_2	$NaHCO_3$	1.9091	0.5238
	CO_2	$Fe(HCO_3)_2$	2.0211	0.4948
CO_3	CO_3	$CaCO_3$	1.6678	0.5996
	CO_3	$MgCO_3$	1.4053	0.7116
	CO_3	Na_2CO_3	1.7666	0.5661
	CO_3	CO_2	0.7333	0.1364
OH	OH	$Mg(OH)_2$	1.7150	0.5831
	OH	$Ca(OH)_2$	2.1780	0.4591
	OH	NaOH	2.3521	0.4252
	OH	Na_2CO_3	6.2331	0.1604
SO_4	SO_4	$MgSO_4$	1.2532	0.7980
	SO_4	$CaSO_4$	1.4171	0.7057
	SO_4	Na_2SO_4	1.4788	0.6762
	SO_4	$FeSO_4$	1.5813	0.6324
	SO_4	$BaSO_4$	2.4300	0.4115
	SO_4	SO_3	0.8334	1.1998
Cl	Cl	$MgCl_2$	1.3430	0.7446
	Cl	$CaCl_2$	1.5650	0.6390
	Cl	NaCl	1.6486	0.6066
	Cl	KCl	2.1026	0.4756
	Cl	$AgNO_3$	4.7913	0.2087
	Cl	HCl	1.0284	0.9724

	Given	Wanted	Factor	Reciprocal
NO_3	NO_3	$Mg(NO_3)_2$	1.1961	0.8361
	NO_3	$Ca(NO_3)_2$	1.3231	0.7558
	NO_3	$NaNO_3$	1.3064	0.7655
PO_4	PO_4	$Mg_3(PO_4)_2$	1.3839	0.7226
	PO_4	$Ca_3(PO_4)_2$	1.6325	0.6126
	PO_4	Na_3PO_4	1.7260	0.5794
	PO_4	NaH_2PO_4	1.2632	0.7916
	PO_4	Na_3PO_4	1.7260	0.5794
	PO_4	Na_2HPO_4	1.4946	0.6691
	PO_4	$Na_2HPO_4.12H_2O$	3.7707	0.2652
$Ca(HCO_3)_2$	$Ca(HCO_3)_2$	$CaCO_3$	0.6174	1.6197
	$Ca(HCO_3)_2$	$NaHCO_3$	1.0365	0.9648
	$Ca(HCO_3)_2$	CO_2 (boiler Conditions)	0.2716	3.6819
	$Ca(HCO_3)_2$	CO_2 (complete reduction)	0.5432	1.8409
$CaSO_4$	$CaSO_4$	Na_2SO_4	1.0434	0.9584
	$CaSO_4$	$CaCO_3$	0.7351	1.3604
$CaCl_2$	$CaCl_2$	NaCl	1.0533	0.9494
	$CaCl_2$	$CaCO_3$	0.9017	1.1090
	$CaCl_2$	$CaCl_2.H_2O$	1.1623	0.8604
	$CaCl_2$	$CaCl_2.6H_2O$	1.9740	0.5066
CaO	CaO	$CaCl_2$	1.9794	0.5052
	CaO	$CaCO_3$	1.7847	0.5603
	CaO	$Ca(HCO_3)_2$	2.8907	0.3459
	CaO	$CaSO_4$	2.4279	0.4119
$Mg(HCO_3)_2$	$Mg(HCO_3)_2$	$CaCO_3$	0.6839	1.4622
	$Mg(HCO_3)_2$	$NaHCO_3$	1.1481	0.8710
	$Mg(HCO_3)_2$	$MgCO_3$	0.5762	1.7355
$MgCO_3$	$MgCO_3$	Na_2CO_3	1.2570	0.7955
	$MgCO_3$	$Mg(HCO_3)_2$	1.7355	0.5762
$MgSO_4$	$MgSO_4$	$CaCO_3$	0.8313	1.2029
	$MgSO_4$	Na_2SO_4	1.1800	0.8475
	$MgSO_4$	$MgSO_4.7H_2O$	2.0476	0.4884
$MgCl_2$	$MgCl_2$	NaCl	1.2276	0.8146
	$MgCl_2$	$CaCO_3$	1.0508	0.9517
$Mg_2P_2O_7$	$Mg_2P_2O_7$	Mg	0.2184	4.5788
	$Mg_2P_2O_7$	$MgCl_2$	0.8553	1.1692
	$Mg_2P_2O_7$	$MgSO_4$	1.0812	0.9249
MgO	MgO	Mg	0.6032	1.6578
	MgO	$MgCO_3$	2.0913	0.4782
	MgO	$Mg(HCO_3)_2$	3.6293	0.2755
	MgO	$Mg_2P_2O_7$	2.7616	0.3621
	MgO	$MgSO_4$	2.9857	0.3349
$NaHCO_3$	$NaHCO_3$	Na_2CO_3	0.6309	1.5850
NaOH	NaOH	Na_2CO_3	1.3248	0.7548
Na_2SO_4	Na_2SO_4	$Na_2SO_4.10H_2O$	2.2682	0.4409
Na_2HPO_4	Na_2HPO_4	PO_4	0.6691	1.4945
	Na_2HPO_4	$Na_2HPO_4.12H_2O$	2.5222	0.3965
$Na_2HPO_4.12H_2O$	$Na_2HPO_4.12H_2O$	PO_4	0.2653	3.7693
Na_2O	Na_2O	Na	0.7419	1.3479
	Na_2O	NaCl	1.8858	0.5303
	Na_2O	Na_2CO_3	1.7098	0.5849
	Na_2O	$NaHCO_3$	2.7101	0.3690
	Na_2O	$NaNO_3$	2.7424	0.3646
	Na_2O	NaOH	1.2906	0.7748
	Na_2O	Na_2SO_4	2.2914	0.4364

Short-Circuit Currents in Industrial Plants

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A SIMPLE electric circuit consists of a source of electricity and a means of using it, connected by two conductors for outgoing and for return of load current (Figure 1). The amount of current that normally flows through the conductors is that which is required to operate the motor, light, heater and other loads.

The conductors of an electric system are separated by non-conducting material which sometimes "breaks down" and allows the conductors to touch, or permits an arc to form across the break. When this happens, the flow of current is no longer related to the load requirement, but is limited only by the capacity of the supply source. Hence, a very high short-circuit current flows—a current which may vary from a few to several hundred times the magnitude of the normal load current (Figure 2).

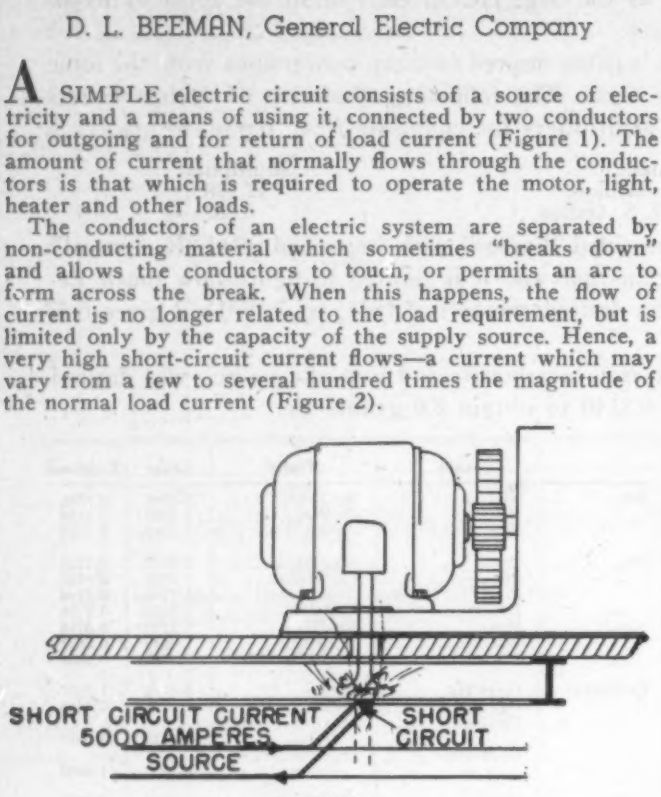

FIGURE 2

It is important to remember that the magnitude of the load current is determined by the amount of work that is being done, and bears little relation to the size of the system supplying the load. However, the magnitude of the short-circuit current is practically independent of the load. It is directly related to the size or capacity of the power source. The larger the apparatus which supplies power to the circuit, the greater the short-circuit current will be.

These two currents are analogous to the flow of water in a hydroelectric plant. The amount of water that flows under normal conditions is determined by the load on the turbines. Within limits, it makes no difference whether the reservoir behind the dam is large or small. This flow of water is comparable to the flow of load current in the distribution system in the factory.

On the other hand, should the dam break, the amount of water that will flow will depend upon the capacity of the reservoir, and will bear no relation to the load on the turbines. Whether the reservoir is large or small will make a real difference in this case. This flow of water is comparable to the flow of current through a "short" in the distribution system. The load currents do useful work, like the water that flows down the penstock through the turbine water wheel. The short-circuit currents produce unwanted effects, like the torrent that rushes madly downstream when the dam breaks.

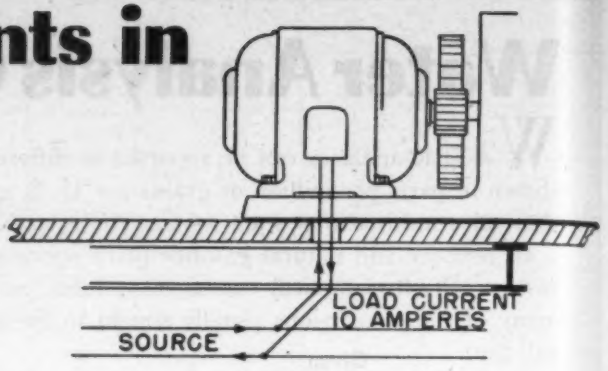

FIGURE 1

The flow of short-circuit current must be stopped in the shortest practical time, least it damage considerable equipment, cause fires, or even cause injury to nearby personnel. Normally, circuit breakers, and sometimes fuses, are used to open the faulty circuit to stop the flow of short-circuit current.

These circuit breakers have two functions and two current ratings. The first function is to carry normal load currents, and, when necessary, to switch them (Figure 3). This function requires a continuous current capacity designated by the ampere rating on the nameplate of the breaker. Fused switches are sometimes used for this purpose also.

The second function of these breakers is to open the circuit to stop the flow of short-circuit current into a fault; in other words, to interrupt the short-circuit (Figure 4). The ability of the breaker to open short-circuit current is given in amperes or kva and is known as the interrupting capacity rating.

The circuit breakers or fuses have a definite limit in their ability to interrupt short-circuit current, just as they have a definite limit in their ability to carry load current. The purpose of giving the circuit breakers an interrupting-capacity rating is to tell the user how much short-circuit current the device can be depended upon to open safely, just as the ampere rating tells how much load-current the breakers will carry safely. Not all devices have the same interrupting capacity for dealing with short-circuit currents, just as all devices do not have the same ampere capacity for carrying load current. Hence the circuit breaker or fuse must be so selected that its interrupting-capacity rating is not less than the short-circuit current which the system will deliver, just as it must have a continuous-ampere rating that is not less than the current drawn by the load.

It is not possible to prevent short circuit entirely. However, by using breakers or fuses of adequate interrupting capacity rating, it is possible to minimize their effects on the system.

When the short-circuit current delivered by the system, is in excess of the interrupting capacity rating of the short-circuit protective device, i.e., the breaker or fuse, this protective device may not successfully open the circuit, and dangerous consequences may follow.

Because the possible consequences of using breakers or

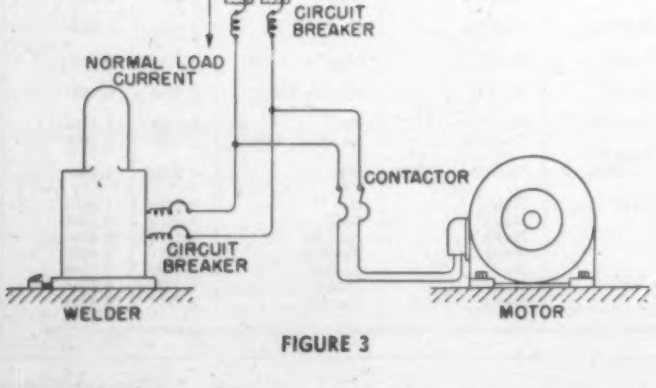

FIGURE 3

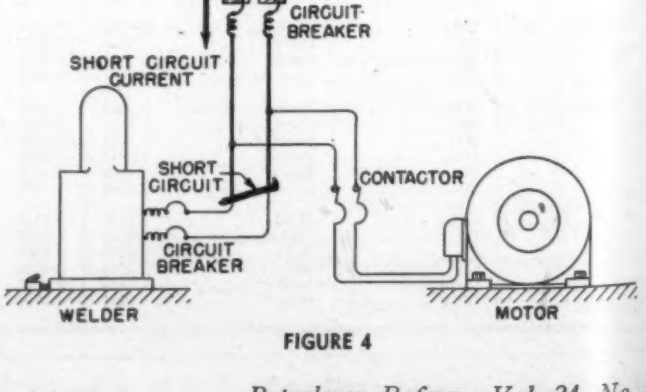

FIGURE 4

fuses of inadequate rating are not always understood, inadequate devices are often installed without full realization of the risk that is being taken. However, inadequate short-circuit protective equipment is not only dangerous, but uneconomical.

Here is why the use of inadequate short-circuit protective equipment is dangerous: When the short-circuit device fails, a condition equivalent to a short circuit occurs within the device itself. This condition releases a tremendous amount of uncontrolled energy within the housing of the device, and may cause intense heat or a violent explosion. This explosion may cause parts to be hurled about with high velocity, and may cause much hot gas to be emitted and spread over an area of several feet or more. In many old low-voltage systems (600 volts and below), inadequate oil-filled breakers are used. These breakers usually have a very low interrupting-capacity rating, and when they attempt to open short-circuit currents beyond their rating, burning oil may be thrown over a considerable area, and a fire may shut down the plant, destroy other equipment, and injure personnel.

Whether the short-circuit protective devices are oil-filled or air-type breakers, or fused disconnecting switches, the fact that they do not provide adequate protection means danger for anyone who happens to be near when they fail. Unfortunately, experience has shown that when a failure occurs, usually someone is near the device.

Here is why inadequate devices are not economical: When the device fails, the condition is equivalent to a bus fault, and hence causes much more load to be shut down, with consequent loss of production. For instance, if circuit breakers or fuses of adequate interrupting capacity had been used in

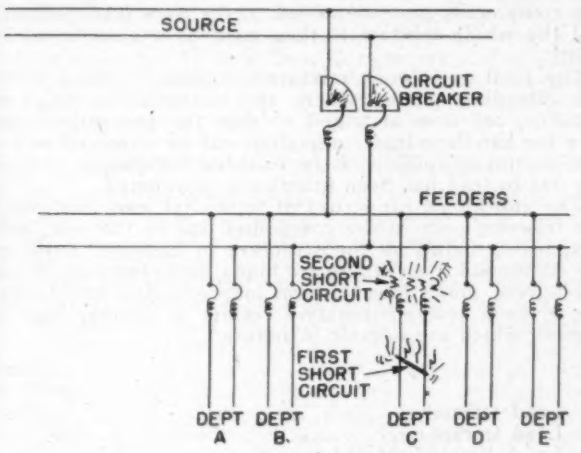

FIGURE 5

the feeder to Department C (Figure 5), the device would have opened the first short circuit on the cable to Department C, and other departments would not have been affected.

The following actual case histories show the results of inadequate short-circuit protection.

In a New England plant a fault occurred on a motor circuit. The branch-circuit fuse (that is, the fuse in the circuit to the motor) which protected this circuit was inadequate, and consequently blew up and caused a fault. The main fuses between the source and branch-circuit fuse were too small, and failed. The main breaker was also of insufficient interrupting capacity, and it failed, too. The fault was finally cleared when the power company's circuit breaker tripped open. In this case, the loss of production of the entire plant was caused by a fault that could have been confined to one small motor circuit. It shows how inadequate short-circuit devices can be a hazard to continuity of production.

In a plant in the Middle West, one small circuit breaker of inadequate interrupting capacity failed. It spread carbon over the switchboard, thereby causing eight other breakers to fail within two weeks' time. Eventually, a new board with adequate circuit breakers was installed and no further difficulties were encountered. This plant not only lost production, but was obliged to buy two switchboards—loss of production and extra expense that could have been avoided if the original circuit breakers had been of adequate interrupting capacity.

Circuit breakers of insufficient interrupting capacity were installed in a plant in the South. The users had been warned that the breakers were too small. Within three years so many of them had failed on short-circuit currents that all of these originial breakers had to be replaced with adequate ones.

A certain plant was continually obliged to replace circuit breakers because they failed. The operators thought that these failures were a regular part of power-system maintenance. When the plant engineer was shown that the circuit breakers were too small, he bought breakers with higher interrupting capacity. Since then, there has been no circuit-breaker trouble. In this case, the lack of understanding the short-circuit problem materially increased the maintenance cost of the power system.

To have a safe power system with low maintenance cost and high service continuity, it is necessary to have adequate circuit breakers throughout the system.

Adequate Short-Circuit Protection

There are certain steps which can be taken to insure adequate short-circuit protection in a plant distribution system. These steps are:

1. Accurately determine the short-circuit currents available. In the past few years, we have learned how available short-circuit current can be accurately calculated at any point in a power system. The calculating procedures have been verified by many tests on actual systems and in short-circuit laboratories. Some former fallacious ideas, which lead to many installations of inadequate fuses and circuit breakers, have been dispelled. For example, the idea that only 20,000 amperes fault current could be obtained at 480 volts has been dispelled by actual measurements of currents of the order of 100,000 amperes at 480 volts.

If the plant operator cannot calculate these short-circuit currents, then his consulting engineer, or the utility company's engineer, or the application engineers of large electrical manufacturers can calculate them for him. Several instructive articles which might be helpful have been published on short-circuit calculations. The method is not too complicated. Until the magnitude of short-circuit currents is known, it is not possible to be sure that the short-circuit protection is adequate.

2. Install only circuit breakers or fuses of known adequate interrupting-capacity rating. Devices of adequate rating can be obtained to meet the requirements of all industries.

Other factors to keep in mind are:

Prepare for load growth—If the system is installed with circuit breakers that are only large enough for present requirements, the circuit breakers will become too small, from an interrupting standpoint, when capacity is added. The system should be designed, and the circuit breakers should be selected on a basis that will provide for expansion, without exceeding the circuit-breaker interrupting-capacity ratings. This expansion can be done at practically no added expense by employing a modern power-distribution system.

Main and auxiliary switchboards in hundreds of plants in operation today were installed years ago when the plants were small. The power demand was limited then; therefore, small transformers were all that was required to supply the plant. The switchboards were probably adequate then, too. But as the plants grew, more power was needed. New feeders were added to carry the new load, and new transformers were added to the bus to supply the added load. In most cases, no thought was given to the breakers, because they carried their load currents satisfactorily. However, when new transformers were added, the capacity of the power supply increased, and hence the available short-circuit current also increased. This higher short-circuit current would impose added interrupting duty on the old breakers, if they were required to clear a faulty feeder cable. Often this added short-circuit current was sufficient to bring the total short-circuit beyond the ability of those existing breakers. But, through oversight, nothing was done about it, leaving the plant vulnerable to a major shutdown if a fault occurred and one of those old breakers failed to clear it.

Failure to consider the effect of increased short-circuit currents has probably been the most common single cause of many of these older installations being unsafe from a short-circuit protection standpoint.

Do not be complacent—Many systems which have been operating for years have never had a major short circuit. Operators of these systems have come to believe that short-circuits never occur, so do not bother about interrupting-capacity rating of breakers. This belief is comparable to the assumption that fire insurance is not necessary because the plant has never burned down. The older the system grows, the weaker the insulation becomes, and the greater the possibility of major short circuits. The breakers, too, are often inadequate in these old systems, and when a short circuit does occur, it is almost certain to cause a major shutdown, with possible damage to other property, as well as loss of production.

The Manufacture of Aviation Gasoline

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THE manufacture of aviation gasoline has taken rapid strides in recent years, especially in the field of preparing new types of hydrocarbons and enlarging the study of the value of cracked gasolines. It is therefore interesting and important to review the most recent advances in the new methods of manufacture.

The important objective in the manufacture of power fuels, such as the gasolines, is the desirability to obtain the highest possible anti-knock value. The methods to accomplish this consist, on the one hand, to produce gasolines which, due to their structure or otherwise, possess an inherent high octane number and on the other hand, to produce fuels also though not high in octane number which possess a very high capacity for increased octane number upon mixing them with tetraethyl lead. Under the last-named heading, susceptibility to lead, one understands that it is the property of a gasoline to show an increase in the octane number upon small additions of tetraethyl lead. This peculiar property is not shown by all types of gasolines even though many of these fuels may show the same physical properties.

Even though both of the above-mentioned methods are quite dissimilar as far as obtaining this increased octane number, there are, nevertheless, gasoline fuels also which show both of these properties simultaneously—that is, they possess an inherently high octane number and at the same time are susceptible to further increases in octane number when small amounts of tetraethyl lead are added.

Tetraethyl Lead

When small amounts of tetraethyl lead are added to a low-octane fuel the results of burning this fuel in the motor can be compared somewhat, although not an exact comparison, to the action of digitalis on the human heart. A minute amount of digitalis reacts upon a weakened heart by securing a more complete output of energy, obtaining this increased output at a subdued, regular rate by which the over-all activity is volumetrically increased.

Tetraethyl lead behaves in somewhat similar fashion in its action in the gasoline engine, securing a better or complete use of the energy bound up in the gasoline and which is thus liberated steadily and evenly. This comparison is not an exact analogy however, since the reasons for using the compounds in each case are, of course, quite different.

A power gasoline containing tetraethyl lead was first marketed in Dayton, Ohio, in 1923 under the name of "Ethyl gasoline." This material became very popular so that the demand rose quite rapidly. After a setback in 1924 occasioned by some accidents during the manufacture of tetraethyl lead, the ban against its use was lifted in 1926, when it had been shown that with care and handling this substance there is practically no danger to operators employed in its manufacture or in blending plants. Tetraethyl lead is practically harmless in the low concentration that it is used in preparing anti-knock gasoline when it is handled with the proper precautions.

Since 1926 a great variety of chemical substances have been prepared and tested out for their anti-knock value in efforts to improve the lead compound but there has been no substitute obtained to date which commercially competes with tetraethyl lead.

In preparing this anti-knock material an alloy of lead and sodium is prepared and then reacted with ethyl-chloride. The reaction takes place as follows:

$$4\,PbNa + 4\,C_2H_5Cl = Pb(C_2H_5)_4 + 4\,NaCl + 3\,Pb$$

The procedure is due to Kraus and Callis.[1] The manufacture, however, is not quite as simple as is shown in the above equation. Many side reactions take place with the formation of by-products and the course of the reaction only becomes optimum within the ranges of definite pressures and specified temperature limits. Beside, pure tetraethyl lead is quite susceptible to high temperatures and then decomposes very easily so that the process requires accurate control in order to prevent the decomposition of the compound at dangerous rates.[2]

Tetraethyl lead as such cannot be directly used as an anti-knock material due to the accumulation of lead oxide in the motor, the oxide being a product of the decomposition of the lead compound. It had been shown early that this disadvantage can be overcome by the addition of small amounts of easily-decomposed halogen compounds, such as dichlor- or dibrom-ethylene. Apparently the lead finally escapes in the form of lead bromide (vapor) with the exhaust gases leaving the motor. In other words, these halogen compounds must be added to the pure lead compounds and the whole mixture is then used as a gasoline addition agent.

The total anti-knock mixture is usually colored strongly red. Blending plants, where this material is mixed with gasoline, are now arranged so that the precautions necessary for handling lead compounds can be observed and with a minimum of spilling of the material the danger of poisoning due to lead has been practically eliminated.

The anti-knock properties of tetraethyl lead, however, are not inherent only in the compound due to the lead, but, as it appears, mainly in the structure of chemical build-up of the compound itself; there are many lead preparations showing a very much lower action in preventing knock. Below are given a few comparative results of several lead compounds which are organic in nature.[3]

	Anti-Knock Coefficient
Lead tetraethyl	118.
Lead tetraphenyl	70.
Lead diethyldichloride	79.
Lead diphenyldimethyl	115.
Lead diphenydibromide	71.
Lead tri-p-xylyl	77.
Lead ethylxanthate	8.
Lead thio-acetate	10.

Tetraethyl lead also increases the spontaneous-ignition temperature of gasolines. Mardels[4] gives the following values:

Tetraethyl lead—0.5 g per 1. Raises the spontaneous ignition temperature approximately 105° C.

Tetraethyl lead—1.0 g per 1. Increases this temperature 130° C.

One cannot discern any proportional relations here between increase in ignition temperature and anti-knock value, notwithstanding that all anti-knock compounds result in an increase of the spontaneous-ignition temperature and all pro-knock materials show a decrease of this temperature. The rate or increase in anti-knock value may not be at all equal to the spontaneous-ignition temperature. For instance, it has been shown for the following compounds:

0.1 percent by weight of:

Diethyl selenium	Result in increase of ignition temperature.	140°C
Iron carbonyl		130°C
Tetraethyl lead		90°C
Nickel carbonyl		40°C

Isoamylnitrite, a pro-knock compound, shows the following depressions of the spontaneous ignition temperature:

2 percent	68°C
5 percent	100°C
10 percent	128°C

The mechanism of the reaction which represents the combustion of a leaded gasoline has not as yet been defi-

nitely ascertained. Nevertheless, many theories have been developed in this field but none have been definitely proven. Many times a working theory has finally been proven to be untenable. For instance, one assumed that the anti-knock material possessed a definite, or positive, catalytic action wherein the combustion was actually accelerated in the initial stages, which prevented large, instantaneous increases of pressure and sudden liberation of a large amount of potential energy. One even assumed that colored compounds were able to absorb or minimize rapid evolution of energy, believing that the combustion of the gasoline and its preliminary vaporization actually was accelerated.

The first anti-knock agent which was tested out based on such reasoning was ordinary iodine. The results obtained at that time actually appeared to follow this working theory very well since iodine was shown later to be quite a good anti-knock agent. Further tests at a later date, made with oil-soluble dyes, showed this theory to be untenable.

Another theory claimed that the anti-knock material was, in reality, a negative catalyst which deactivated the catalytic action of the metal walls of the engine cylinder during the combustion of the gasoline. This idea was later found to be without value.

We know today that the ignition of a gas mixture (and this includes the phenomenon of knock itself) is not a definite instantaneous reaction but is always preceded by an auto-oxidation mechanism; anti-knock materials effectively hinder this auto-oxidation while pro-knock materials definitely accelerate the reaction.[8]

There are various gasolines which do not react with additions of tetraethyl lead in similar fashion; that is, the octane number is not increased proportionately with gasolines of various origins.

The natural gasolines, as well as very light gravity gasolines, such as casing-head gasolines, respond very much better to additions of lead than do the cracked gasolines. It is also very important to note that sulphur compounds hinder the action of lead in attempts to secure large increases in the octane value.

Desulphurization of Aviation Gasolines

The fact that sulphur compounds adversely affect the octane increase upon adding tetraethyl lead to a gasoline has lead to a study of removing various sulphur compounds from gasoline fractions derived from high-sulphur crude oil.

Birch and Stansfield[6] had found that definite sulphur compounds varied in their effect in decreasing the effect of tetraethyl lead additions. They tested out known mixtures of sulphur compounds in gasoline blends, obtaining a sulphur content of 0.1 percent in the mix. The retardation of the octane number upon lead additions increased in the following range: hydrogen sulphide, thiophene, alkyl sulphide, mercaptanes, disulphides and trisulphides. There are even some sulphur derivatives which not only obscure the octane number but actually are known to be pro-knock compounds. Pro-knock tendency could easily be demonstrated in the case of ethyl-trisulphide and various mercaptans. Continuing along these investigations it was also found that mixtures of heptane with olefines and diolefines showed a slight lead susceptibility when 0.1 percent sulphur and ethylene-dissulphide was added to the mixture.

Schultz and Buell[7] had made similar observations in 1935. Schultz and Alden[8] show that lead susceptibility is not only lowered by the presence of sulphur but that also iso-octane aviation mixtures show a lower anti-knock value when the gasoline was manufactured from a sulphur-containing raw, stock. These investigators removed the sulphur compounds contained in the benzine by passing the vapors over bauxite at a temperature of between 700°-750° F.

Bauxite reacts catalytically with many sulphur compounds, splitting the latter into hydrocarbons and hydrogen-sulphide.

The following data of Schultz and Alden give an insight into the action of sulphur on the lowering of anti-knock value upon additions of lead: For the investigations which Schultz and Alden carried out a natural gasoline from Borger crude was used, (vapor pressure of 0.84 kg/sq.cm., absolute). The sulphur contents of the gasoline was 0.037 percent, the anti-knock value showed 67.2 ASTM-octane value. After successive desulphurization down to a value of 0.008, then to 0.004, and finally to 0.002 percent, the following values were obtained after the addition of 0.5 cubic centimeters of tetraethyl lead per gallon, (or 0.132 cc's per liter):

1. The gasoline before sulphur removal showed ASTM octane of 72.2.
2. The 0.008 percent sulphur gasoline—an octane value of 76.5.
3. The 0.004 percent sulphur gasoline—an octane number of 76.8.
4. The 0.002 percent sulphur gasoline—an octane number of 77.0.

The removal of sulphur from this gasoline therefore had improved the octane number from a 67.2 to a value of 77.0 for the lowest-sulphur-content material.

Using larger amounts of tetraethyl lead secures a much greater rise in octane value; for instance, an addition of 6 cubic centimeters of tetraethyl lead per gallon to the above desulphurized gasolines showed the following octane numbers:

1. The gasoline (before sulphur removal)..... 86.6
2. The gasoline of 0.008 percent sulphur..... 91.2
3. The gasoline of 0.004 percent sulphur..... 92.8
4. The gasoline with 0.002 percent sulphur.... 93.2

The addition of ½ cubic centimeter of tetraethyl lead shows a difference of 4.8 points between the untreated and the drastically desulphurized gasoline, while the use of 6 cubic centimeters of tetraethyl lead results in a difference of 6.6 in octane number. These results agree with the work of Schulz and Buell[9] who had shown in 1935 that the effect of a thorough desulphurization calls for only small additions of tetraethyl lead to obtain high octane values.

In the case of aviation gasoline composed of a mixture of iso-octane and natural gasoline the lead susceptibility is practically proportional to the quantity of sulphur-free gasoline that is present in the mixture. This is of great advantage since larger quantities of straight-run gasoline can be mixed with iso-octane to produce a finished product of required octane value. The following figures have been obtained for a pentane-free natural gasoline from Borger crude oil using an addition of 3 cubic centimeters per gallon of tetraethyl lead to obtain a 100-octane aviation gasoline. The saving in the quantity of iso-octane needed in this mixture can be seen below in relation to the sulphur content of the natural gasoline:

Sulphur Content of Borger Gasoline	Percent Iso-Octane
0.056 percent	66.0
0.017 percent	58.5
0.013 percent	55.2

Catalytic Dehydrogenation

Dehydrogenation using catalysts is an important process for preparing butylene and propylene from the butanes and propane. These olefine hydrocarbons are the raw materials in the manufacture of iso-octane. According to Grosse, Ipatieff, Egloff, and Morrell,[10] the yields of these olefines are considerably higher in the catalytic process than are obtained by thermal cracking. In the case of ordinary cracking only about 15 percent of the theoretical olefines are obtained, while in the case of dehydrogenation 85-95 percent of theoretical olefines can be recovered. That is an appreciable increase and shows high efficiency in conversion of refinery gases. The reason for the low yield in the case of thermal-cracking is due to the fact that the bond between carbon and carbon is broken which usually leads to formation of carbon and methane.

In the case of catalytic cracking it has been shown that hydrogen actually is split off. Frey and Huppke[11] employ a chromium oxide catalyst and were able to dehydrogenate butane at 350-500° C. Grosse and Ipatieff[12] mention the metals in the fourth, fifth and sixth groups of the periodic system as very effective dehydrogenation catalysts when used with the proper carrier. One of the most efficient substances is aluminum oxide. These catalysts show a long period of activity and direct the reaction toward true dehydrogenation:

$$C_nH_{2n+2} \rightarrow C_nH_{2n} + H_2$$

Commercially the process is carried out as follows: the gases are brought to a temperature of 600-650°C, (the reaction temperature), in a pipe heater, from which they are lead into the catalytic chamber. These are built along conventional lines such as heat exchangers, the catalyst being placed in the tubes of the exchangers. A heat-absorbing liquid is circulated around the outside of the tubes in order to control the temperature. A mixture of chromium and aluminum oxide is the catalyst. This mixture is not susceptible to poisoning by impurities, although the precaution must be taken that iron oxide does not contaminate the material. The tubes, therefore, which contain the catalyst are in every case manufactured from special steel. Coke and carbonaceous material finally will form on the catalyst, and these impurities are eventually burnt off the material by oxidation with gases containing considerable air. The reaction products are cooled and condensed under pressure. The fluid products are fractionated also under pressure while the non-volatile products

are removed in a tower for scrubbing remnants of gases entrained in the higher-boiling olefine fractions.

Iso-Octane

Iso-octane has been industrially manufactured since 1934. It was also the first substance used to determine anti-knock values of other fuels, having been employed in mixtures with normal heptane. It is not used directly as a fuel but most commonly always in mixtures with gasolines and other volatile products. It is important to remember the meaning of high anti-knock in gasolines, since an increase in octane number from 90 to 100 is equivalent to 15-30 percent greater energy output. Pure iso-octane shows a boiling point of 99.4° C. specific gravity of 0.691, and a Reid vapor pressure of 0.15 kg. per sq. cm.

Commercially the material is obtained by polymerizing normal butylene and iso-butylene, obtaining iso-octylene. The latter is then hydrogenated to iso-octane. The process as patented by Universal Oil Products Company, is as follows: the mixtures of iso and normal butylene are led into a pipe heater and heated to 300-450°C, the gases then being led to the contact chambers containing phosphoric acid as a catalyst. This catalyst is prepared by saturating porous material such as pumice stone, silica gel, etc., with phosphoric acid. After saturating the carrier with the acid it is then calcined further in the presence of the acid. A series of patents to Ipatieff[33] covers the process as described above.

The first reaction chamber containing the catalyst is also built according to the principles of heat exchangers. Hot water is passed around the tubes, for the purpose of regulating the temperature by carrying off the exo-thermic heat of the reaction. The process is carried out at a pressure of 42-56 kg. per sq. cm.

The reaction products are next passed into a fractionating column in which the butanes present in the original mixture are finally separated. The reflux consists of iso-octene and the trimer dodecylene which forms in small amounts.

The mixture is further fractionated in a second column separating iso-octylene and dodecylene. The iso-octylene is a mixture of various isomers and has a boiling range of 93-127°C. It actually shows an anti-knock value of 83. This is the material which is then hydrogenated to iso-octane. Iso-octane obtained by this method shows an anti-knock value of 96. The iso-octane thus obtained has a boiling range of 93-126°C. As such it is not a motor-fuel product due to its lack of volatility. It is used in blending with a straight-run or aromatic type gasoline to obtain an aviation material of 100-octane number.

Isopentane

Isopentane is used in blending to obtain the aviation gasolines. It is not being synthetically manufactured to any great extent. Its sources are the natural and refinery gases. It shows an octane value of 90 (research method) but will show a value of 92-100 (mixed octane value) when added to ethyl-benzene. In preparing the aviation gasolines it is desirable to limit the use of butane (90) and iso-butane (99) due to their high vapor pressure and due to their tendency to form ice on the carburetor. Normal pentane of 50-octane number also is undesirable, so that the method is to remove these materials from the blending aviation stock and in their stead add iso-pentane in order to obtain the proper volatility of mixtures made with blending gasolines and iso-octane. In this manner less of the expensive iso-octane need be used. Generally, the addition of isopentane need not amount to more than 15 percent.

Egloff, Morrell, and Nelson[34] show the following values for a mixture of 74-octane aviation gasoline of 0.49 AT. Reid vapor-pressure, iso-octane and isopentane containing 3 cubic centimeters of tetraethyl lead per gallon, of 100-octane value:

Isopentane	74 Octane Benzine (%)	Iso-Octane	Reid Vapor Pressure
0	38.	62.0	4.0
10	37.2	52.8	5.8
17	36.7	46.3	7.0
30	35.7	34.3	9.5
40	34.9	25.1	11.4

These figures show the value of manufacturing and properly blending iso-pentane to obtain valuable aviation gasolines. To obtain this material, fractionation is necessary, which operation must be conducted very carefully to secure close-cut stock.

Iso-Propyl Ether

Iso-propyl ether shows good anti-knock values as opposed to the action of di-ethyl-ether. Its boiling point is 67.8°C., the specific gravity shows 0.725 at 20°C. (water at 4°C.). Its freezing point, which is a valuable constant to be determined for all aviation gasoline, is —87°C.

According to B. Howes[35] there is required 3 cubic centimeters per gallon of tetraethyl lead plus 40 percent iso-propyl-ether to produce 100-octane aviation gasoline, while under similar conditions 45 percent iso-octane are required to produce 100-octane gasoline of equal vapor pressure, (0.42 at. Reid). Iso-propyl-ether shows the disadvantage of being somewhat soluble in water. Therefore, iso-propyl-ether gasolines are apt to contain some quantities of moisture inasmuch as storage tanks usually contain water at the bottom of the tank. The tendency for ethers to develop peroxides during storage is also a factor which has to be reckoned with. B. Howes,[35] and Buck and Alden[36] mention this in their investigations.

Neohexane

According to the theories of organic chemistry the term polymerization comprises a reaction in which two or more molecules are grouped together into a new compound in such a manner that the original molecule undergoing the reaction can again be recovered or regenerated in a simple manner. An example of this is the conversion of acetaldehyde into paraldehyde and the regeneration of acetaldehyde from the last mentioned compound.

This fact is noted inasmuch as the concept of polymerization as employed in the petroleum industry is generally somewhat different, although identical; that is, it is usually termed a condensation. As an example of a typical condensation one can mention the formation of aldol from acetaldehyde.

Iso-octylene is formed from one molecule of butylene and one molecule of iso-butylene; a mixture of iso- and normal pentane is obtained from one molecule of ethylene and one molecule of propane. These reactions in the case of the iso-octylene are hardly a polymerization according to exact terminology nor is the case of the pentane a typical example of alkylation.

The term alkylation comprises the concept wherein there is an exchange of an hydrogen atom (or a substituent) with an alkyl radical. Typical alkylation reactions are actually those which undergo, for instance, a Friedel-Craft synthesis, or for instance, a Fittig synthesis.

Nevertheless the term alkylation has been applied to reactions such as those mentioned above. For example, the reaction forming pentane from ethylene and propane.

Neohexane is obtained in analogus fashion by the alkylation of ethylene and isobutane. This alkylation actually comprises a special case termed polymerization as employed in the petroleum industry today.

Neohexane is one of the five isomers of hexane. Oberfell and Frey[37] describe the following process for this material:

> The manufacture from ethylene and isobutane is carried out thermally without the aid of any catalysts. Operating temperatures are approximately 950° F. (or 510°C.) and pressures of 3000-5000 pounds per square inch, approximately 210-350 at. are employed. The partial pressure of the ethylene in the mixture is kept low in order to prevent the formation of tarry material. The product of the alkylation as obtained by this procedure is a light yellow liquid and contains only a small amount of material boiling above the range of the light gasolines. The alkylate after debutanizing shows the following distillation range:

5 percent	129°F.	(53.9°C.)
10 percent	136°F.	(57.8°C.)
20 percent	142°F.	(61.1°C.)
30 percent	146°F.	(63.3°C.)
40 percent	151°F.	(66.1°C.)
50 percent	157°F.	(69.4°C.)
60 percent	166°F.	(74.4°C.)
70 percent	180°F.	(82.2°C.)
80 percent	206°F.	(96.7°C.)
90 percent	268°F.	(131.1°C.)
95 percent	310°F.	(154° C.)
End Point	370°F.	(187.8°C.)

In order to obtain a better picture of the above distillation boiling points the following table shows the boiling point of the hexanes:

Neohexane	121.5°F.	(49.7°C.)
2,3 dimethylbutane	136.6°F.	(58.1°C.)
2-methylpentane	140.4°F.	(60.2°C.)
3-methylpentane	145.8°F.	(63.2°C.)
n-hexane	155.8°F.	(68.8°C.)

The properties of neohexane are:

Boiling point	121.5°F.
ASTM octane number	94
Specific gravity, 20-4°C.	0.6494
Freezing point	—144.8°F.

The lead susceptibility of neohexane is said to be much

greater than that of iso-octane. Mixed octane numbers for neohexane are shown below:

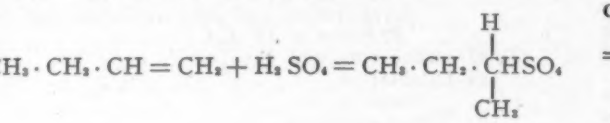
Raw Products	Octane No.	Reid Vapor Pressure
(a) Depentanized raw gasoline	75	0.26 atm.
(b) Technical iso-octane	94	0.10 atm.
(c) Neohexane, very pure	94	0.69 atm.
(d) Isopentane, very pure	90	1.47 atm.

A mixture of: Percent (a)	+	Percent (b)	+	Percent (c)	+	Percent (d)	=	Octane No.
81.5	+	.....	+	.....	+	18.5	=	77.8
54.4	+	24.8	+	.....	+	20.8	=	82.8
54.4	+	12.3	+	21.0	+	12.3	=	83.2
27.2	+	24.7	+	42.0	+	6.1	=	88.6
27.2	+	49.7	+	.....	+	23.1	=	87.8

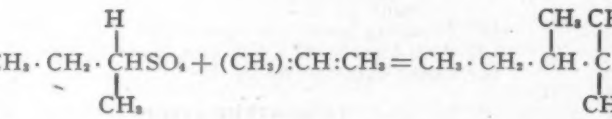
The vapor pressure of all the mixtures is 7.0 pounds. Reid (0.49 at.).

Alkylation With Sulphuric Acid as Catalyst

If sulphuric acid is allowed to react upon a mixture of butylene and isobutane a fairly rapid formation of iso-octane takes place. According to K. G. MacKenzie[18] this reaction really takes place in two steps. In the first step the alkyl ester is formed from butylene and the sulphuric acid. This ester reacts in the second step with iso-butane with the formation or regeneration of sulphuric acid, thus forming the iso-octane. The mechanism of the reaction is as follows:



(I.) $CH_3 \cdot CH_2 \cdot CH = CH_2 + H_2SO_4 = CH_3 \cdot CH_2 \cdot \underset{\displaystyle CH_3}{\overset{\displaystyle H}{\overset{|}{C}}}HSO_4$



(II.) $CH_3 \cdot CH_2 \cdot \underset{\displaystyle CH_3}{\overset{\displaystyle H}{\overset{|}{C}}}HSO_4 + (CH_3):CH:CH_2 = CH_3 \cdot CH_2 \cdot \underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{C}}}H \cdot \underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{C}}} - CH_3 + H_2SO_4$

Optimum concentration of acid is 98-100 percent sulphuric acid, at an optimum temperature of 10-21°C. Other conditions of operation[19] have been reported as optimum using 67 percent strength acid at operating temperatures of 80°C. with contact times of 10-15 minutes. The latter report indicates that the reaction gives even better results using a weaker acid at a somewhat higher temperature than by the use of a stronger acid in the cold. As catalysts for this type of polymerization many foreign patents have also claimed the use of various aromatic sulpho-acids.

Catalytic Reforming

A typical example of this procedure in petroleum refining is the Houdry cracking process. According to Peterkin, Bates and Broome[20] especially high grades of aviation gasoline are manufactured by this process. The process is carried out as follows: The naphtha or a heavy gasoline of 204-260°C. end-point or a heavy fraction boiling around 120-260°C. is heated to a temperature of 454°C. in a continuous process in pipe stills from which the vapors are led directly to the contact chamber. The reaction product leaving the contact chamber passes through a heat exchanger and from there to the fractionating column. The reaction product is thus fractionated into aviation gasoline, naphtha, gasoil and some gas.

The catalyst employed is a highly active aluminum hydrosilicate. Carbonaceous material forms on the catalyst during the reaction. The catalyst is regenerated by burning off the carbon with superheated air in the chambers cut out of the system. The cokey products are thus burnt off the catalyst and the waste gases passed into the atmosphere by way of a turbo compressor.

The turbo compressor furnishes the air for combustion of the cokey material—the air being heated in a special pipe heater. The cost of the catalyst is fairly high at approximately $25,000 for a 10,000-barrel plant. The life of the catalyst is approximately 180 operating days. The catalyst chambers are approximately always in use for a period of about 10 minutes, whereupon a period of 20 minutes will follow which is called the regeneration period. Yields are about 58.8 volume percent of aviation gasoline by reforming of Gulf Coast heavy gasoline, and 32.5 percent of aviation stock when reforming an East Texas heavy gasoline. Gas is formed to the extent of 13 percent in both cases.

The boiling-point range of both of these gasolines is as follows:

	Gulf Coastal	East Texas
I.B.P.	104° F. (40° C.)	104° F. (40° C.)
10 percent off	144° F. (62.2° C.)	132° F. (55.5° C.)
20 percent off	166° F. (74.4° C.)	144° F. (62.2° C.)
30 percent off	184° F. (84.4° C.)	157° F. (64.4° C.)
40 percent off	199° F. (92.7° C.)	174° F. (78.8° C.)
60 percent off	226° F. (107.7° C.)	220° F. (104.4° C.)
80 percent off	256° F. (124.4° C.)	262° F. (127.7° C.)
95 percent off	300° F. (148.9° C.)	298° F. (147.7° C.)
E.P.T.	328° F. (163.3° C.)	334° F. (167.7° C.)

The yields are based on the boiling-point requirement, specifying that 90 percent of the material must distill at 293° F. The Reid vapor pressure is 7 pounds for both samples. The ASTM octane number is between 77 and 79 for both samples.

The addition of 3 cubic centimeters of tetraethyl lead per gallon increased the octane number to 90.5 for the Gulf Coast gasoline and to 92.5 for the East Texas gasoline. The yields, according to United States specifications, are somewhat lower since the requirement here is that 90 percent must distill off at 257° F. The raw stock used for the conversion had the following characteristics:

	Gulf Coastal	East Texas
I. B. P.	154° F. (67.7° C.)	282° F. (138.8° C.)
10 percent	224° F. (106.6° C.)	324° F. (162.2° C.)
30 percent	278° F. (137.7° C.)	344° F. (173.3° C.)
50 percent	334° F. (167.7° C.)	366° F. (184.4° C.)
70 percent	388° F. (197.7° C.)	388° F. (197.7° C.)
90 percent	435° F. (223.8° C.)	424° F. (217.7° C.)
95 percent	448° F. (231.1° C.)	440° F. (226.7° C.)
Octane No.: (A.S.T.M.-Motor)	57.2	34.7

Isomerization

Isomerization is based upon the fact that higher-boiling-point hydrocarbons, especially those of the paraffin series, can be rearranged into new molecular structures so that the reaction product will show an increase in the anti-knock value. This newly adapted procedure is valuable for obtaining high-anti-knock products.

Only recently it has been possible to develop a practical process to carry out these reactions. The isomerization of normal olefines proceeds relatively simply while the isomerization of normal paraffins occurs usually with simultaneous cracking of the paraffin forming at the same time unsaturated hydrocarbons. These reactions are difficult to control. According to Howes,[21] Ipatieff and his co-workers were able to convert 1-butylene into 2-butylene in almost 100 percent yields, using phosphoric acid as a catalyst at 249° C. Zinc chloride, benzol-sulphonic acid, and perchlor acid were also found to be active catalysts for this conversion. According to Howes, Laughlin and Nash were able to convert hexylene into a mixture of the three isomers, using phosphoric acid and silica gel at 300° C. The same investigator mentioned that using zinc chloride as a catalyst, he was able to convert normal heptane into isopentane in about 25 percent yields. The operations were conducted at a temperature of 300-400° C. under nitrogen pressure. It is said that aluminum chloride and molybdenum sulphide also exert an isomerization reaction on paraffins.

Our own investigations were conducted with a crude cracked gasoline, conducting the vapors at 130-200° C. over a mixture of boric acid and bleaching clay as well as over bleaching clay alone. Two parallel runs were made under the same operating conditions. The crude reaction products obtained in each case showed the following properties:

	(a) After Clay Treatment	(b) After Boric Acid-Clay Treatment
D_{15}	0.709	0.703
I.B.P.	38° C.	33° C.
50° C.	2 percent	3 percent
60° C.	6 percent	10 percent
70° C.	9 percent	15 percent
80° C.	16 percent	27 percent
90° C.	24 percent	37 percent
100° C.	30 percent	46 percent
110° C.	39 percent	56 percent
120° C.	50 percent	67 percent
150° C.	75 percent	89 percent
170° C.	91 percent	96 percent
E.P.T.	188 (97 percent)	184 (97.5 percent)
Residue	2 percent (oily)	5 percent (oily)

Before stabilization the gasoline (a) obtained showed an octane number of 60.6 (research method) and gasoline (b) a

value of 67. After stabilizing both products at 40° C. to a vapor pressure of 0.6 at. gasoline (a) showed an octane number of 58 and (b) a value of 59.

Gasolines which had been treated with bleaching clay before the boric-acid treatment remained unchanged after treating with boric acid. The boric-acid-treated gasoline is considerably lower in boiling range which can be explained by the fact that this treatment has caused some isomerization of the olefinic material. After the boric-acid treatment, however, the cracked gasoline, in storage for several days, apparently showed no results. Good results were obtained with other catalysts, such as silicic acid, metaphosphoric acid, zinc oxide, and phosphorous pentoxide. The procedure is not as practical as desired since, after stabilization, the octane number has been found to decrease considerably, offsetting gains otherwise made.

Polymerization

The formation of high-boiling-point hydrocarbons from olefines has been carried out successfully in practical processes. The gasolines which may also be obtained in such processes show an especially high octane number of over 100-200. Various combinations have been proposed to carry out the polymerization reaction. Phosphoric acid as a catalyst has been found most efficient and is commonly used. The patent literature up to 1926 appears to show that the I. G. Company was the first to propose phosphoric acid and its combinations. Mention is also made of United States Patent 1,884,093. A considerable number of patents have also been granted Universal Oil Products Company and Ipatieff.

Polymerization using phosphoric acid has been described in the case of preparing iso-octylene. The polymer gasolines upon being blended with low-octane material appear to give higher octane numbers than can be calculated by the law of mixtures. A few examples will be discussed.

For instance, it is intended to blend 50-50 two gasolines of octane number 40 and 80, the latter being the polymer gasoline. According to the law of mixtures the blended material will calculate to an octane number as follows:

$$\text{Mixed octane No.} = 40\,(0.5) + 80\,(0.5) = 60$$

Actually the mixture would probably show an octane number of 80 instead of 60. Using the above equation the average value for the octane number can be calculated by substituting X for the octane number of the polymer gasoline:

$$80 = 40\,(0.5) + X\,0.5$$

$$X = \frac{80 - (40 : 0.5)}{0.5} = 120$$

The octane number or blending value of the polymer gasoline is therefore 120 in the mixture, while 100 percent of the pure material shows a value of 80.

General Characteristics of Aviation Gasolines

High volatility is very important from the standpoint of flexibility in acceleration or slowing down of aviation motors. However, a volatility beyond a certain range, especially due to the presence of the butanes, leads to iceing of the carburetor or vaporizors. Such gasolines will also show what is known as vapor lock. One therefore stresses the use of gasolines which are free of butane but which contain the isopentane as a substitute which we have mentioned above.

A typical United States army gasoline, 2-95, shows the following properties:

Octane (army meth.)	92
TEL	6 cc. p. gal.
Color	Blue
Reid V. Pres.	0.49 atm.
% S (max.)	0.1%
Dist'n Test	
10%	158 F. 70° C.
50	212 F. 100° C.
90	275 F. 135° C.
Res.	2 %
Freez'g point	—76 F., —24.4 C.

English specifications call for two grades of aviation gasoline as follows:

1) 77-octane standard gasoline
   (a) Distillation test:
   under 75 C., not over 10%
   at 100 C., at least 50%
   at 150 C., at least 90%
   End point.....under 180 C.
   (b) Vapor pressure at 100° F. not over 0.49 at.
   (c) Freezing point not over —50° C.
   (d) Anti-knock value not lower than 77, by CFR-motor method.
   (e) Gum.
      1. Actual gum not over 10 mg. per 100 cc. of liquid. This test is conducted by evaporating the sample in an open glass dish.
      2. Potential gum. 50 cc. of the gasoline must not show more than 10 mg. per 100 cc. after evaporation and after an incubation period of 20 hours at 35° C.
2) 87-octane standard gasoline.
   (a) Distillation.
   Same as 1a.
   (b) Vapor pressure.
   Same as 1b.
   (c) Freezing point not over —60° C.
   (d) Anti-knock: 87 CFR-motor method.
   (e) Gum: same as under 1e.

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Percentage Gasoline Saturation of Absorption Oil
Computed on a Gasoline-Free Basis*
(750 CC Sample)

CC Rec.	% Sat.	CC Rec.	% Sat.	CC Rec.	% Sat.	CC Rec.	% Sat.	CC Rec.	% Sat.	CC Rec.	% Sat.	CC Rec.	% Sat.	CC Rec.	% Sat.
1.0	.133	11.0	1.480	21.0	2.880	31.0	4.311	41.0	5.782	51.0	7.296	61.0	8.853	71.0	10.465
1.5	.200	11.5	1.557	21.5	2.951	31.5	4.384	41.5	5.857	51.5	7.372	61.5	8.932	71.5	10.537
2.0	.267	12.0	1.626	22.0	3.021	32.0	4.456	42.0	5.932	52.0	7.449	62.0	9,011	72.0	10.619
2.5	.334	12.5	1.694	22.5	3.092	32.5	4.529	42.5	6.007	52.5	7.526	62.5	9,090	72.5	10.707
3.0	.401	13.0	1.763	23.0	3.163	33.0	4.602	43.0	6.082	53.0	7.604	63.0	9.170	73.0	10.782
3.5	.468	13.5	1.832	23.5	3.234	33.5	4.675	43.5	6.157	53.5	7.681	63.5	9.249	73.5	10.864
4.0	.536	14.0	1.902	24.0	3.305	34.0	4.748	44.0	6.232	54.0	7.758	64.0	9.329	74.0	10.946
4.5	.603	14.5	1.971	24.5	3.376	34.5	4.821	44.5	6.307	54.5	7.836	64.5	9.409	74.5	11.028
5.0	.671	15.0	2.040	25.0	3.448	35.0	4.895	45.0	6.382	55.0	7.913	65.0	9.489	75.0	11.111
5.5	.738	15.5	2.110	25.5	3.519	35.5	4.968	45.5	6.458	55.5	7.991	65.5	9.569	75.5	11.193
6.0	.806	16.0	2.179	26.0	3.591	36.0	5.042	46.0	6.534	56.0	8.069	66.0	9.649	76.0	11.275
6.5	.875	16.5	2.249	26.5	3.662	36.5	5.115	46.5	6.609	56.5	8.147	66.5	9.729	76.5	11.358
7.0	.942	17.0	2.319	27.0	3.734	37.0	5.189	47.0	6.685	57.0	8.201	67.0	9.809	77.0	11.441
7.5	1.010	17.5	2.389	27.5	3.806	37.5	5.263	47.5	6.761	57.5	8.303	67.5	9.890	77.5	11.524
8.0	1.078	18.0	2.459	28.0	3.878	38.0	5.337	48.0	6.837	58.0	8.381	68.0	9.970	78.0	11.607
8.5	1.146	18.5	2.529	28.5	3.950	38.5	5.411	48.5	6.913	58.5	8.459	68.5	10.051	78.5	11.690
9.0	1.214	19.0	2.599	29.0	4.022	39.0	5.485	49.0	6.990	59.0	8.538	69.0	10.132	79.0	11.773
9.5	1.282	19.5	2.669	29.5	4.094	39.5	5.559	49.5	7.066	59.5	8.616	69.5	10.213	79.5	11.856
10.0	1.350	20.0	2.739	30.0	4.166	40.0	5.633	50.0	7.142	60.0	8.695	70.0	10.309	80.0	11.940
10.5	1.419	20.5	2.772	30.5	4.239	40.5	5.708	50.5	7.219	60.5	8.774	70.5	10.375	80.5	12.023

* Percentages computed after subtracting CCS gasoline recovered from total volume of sample.

Example: Volume of sample 750 CCS
Volume gasoline recovered 10 CC

$$\text{Percent saturation of absorption oil is } \frac{10}{750-10} \times 100 \text{ or } 1.350 \text{ percent.}$$

Operating Procedure for Determining Heat of Combustion Of Gasoline

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MANY of the specifications for aviation gasoline now in effect in the United States include a minimum limit for lower or net heat of combustion. The prescribed procedure is to determine the gross calorific value in an approved oxygen-bomb calorimeter and obtain the net value by making a suitable correction for the latent heat of vaporization of water formed during combustion of the fuel.

Practically all published directions for determining the gross calorific value of aviation gasoline are exemplified by Method 250.2 of the Federal Specification for Lubricants and Liquid Fuels[2]. This prescribes the use of the standard A.S.T.M. method of test for thermal value of fuel oil[1] modified as follows for volatile fuel:

> Fill a dry, weighed, gelatin capsule of suitable size with dry cotton fiber, weigh the capsule again, and record the weight of gelatin and cotton. Fill the capsule by immersing it in the fuel and closing it under the surface. Dry the outside of the capsule, weigh the capsule immediately, and record the weight of the fuel. Wrap the ignition wire around the capsule three or four times and place the capsule immediately in the bomb. Fill the bomb with oxygen at 30 atmospheres pressure, and proceed with the test as outlined in Method 250.1.
>
> Repeat the test if traces of sooty deposits or odor of unburned fuel are noticed when the bomb is opened after combustion.
>
> Corrections. Make all corrections outlined in Method 250.1 and in addition correct for the heat of combustion of the gelatin and the cotton by subtracting from the total heat developed.

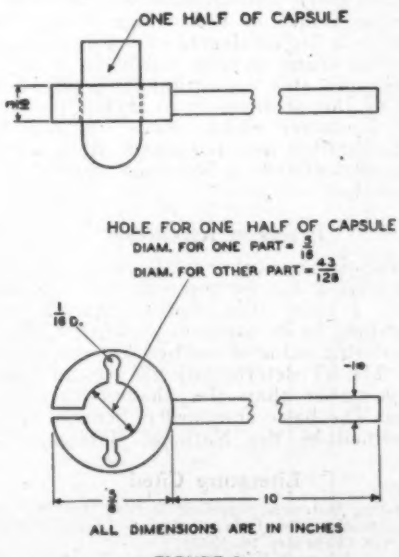
ONE HALF OF CAPSULE
HOLE FOR ONE HALF OF CAPSULE
DIAM. FOR ONE PART = 5/16
DIAM. FOR OTHER PART = 43/128
1/16 D.
10
ALL DIMENSIONS ARE IN INCHES

FIGURE 1

Capsule Holder consists of two parts, one shown with half-capsule in place. Inside diameters, as shown, are suitable for capsules used in authors' laboratory.

THE paper, reprinted from Industrial and Engineering Chemistry, describes details of operating procedure for determining the heat of combustion of gasoline. The degree of precision and the economy of conducting the tests compare favorably with those possible for petroleum products of low volatility.

These directions, obviously, leave a great deal to the imagination of the operator. The authors' laboratory has had occasion to acquire a large amount of experience with this particular determination, and the present paper discusses the details which are missing in the published directions quoted above, and gives specific instructions followed by their operators.

Condition and Size of Gelatin Capsules

The use of a dry gelatin capsule of suitable size is prescribed. As purchased, capsules contain a large and indeterminate amount of water. One batch dried in a desiccator over calcium chloride showed a loss of weight of about 10 percent for the first day, and an additional 4.5 percent in the 20 days following. Complete drying could be effected by heating in an oven at 221° F., but the capsules then became brittle and unusable. It was found that capsules "as received" did not change appreciably during the normal time of the weighing operation, regardless of whether the humidity was high or low, and it appeared that the important feature was to ensure uniform water content in a batch, and to avoid extraneous surface moisture.

Capsules having a suitable capacity of about 0.1 ml. are designated as "No. 00 size" by at least one commercial supplier.

Filling of Capsules

The published directions call for filling a weighed capsule containing a determined quantity of dry cotton, by immersing it in the fuel and closing it under the surface of the liquid. The cotton serves to minimize splashing when the capsule is ignited in the bomb. Ignited asbestos serves the same purpose and has the obvious advantage of contributing nothing to the heat generated during the combustion period. However, by observing certain simple precautions it is possible to dispense with cotton or asbestos. Splashing does not occur if the capsules are completely filled with liquid and free from even the smallest bubble of air or other permanent gas.

The prescribed operation of filling by pushing together the two halves of the capsule below the surface of the liquid fuel can, if necessary, be performed with the fingers. The use of a special brass holder, such as shown in Figure 1, has obvious advantages, particularly as regards the size of the

container and the quantity of fuel required. It is not considered good practice to fill more than one capsule from the portion of gasoline which has been poured into the dish.

Evaporation Losses

The fact that capsules are not perferctly tight is recognized in the published directions, by the provisions for weighing "immediately" after filling, and placing the capsule in the bomb "immediately" after adjusting the ignition wire. This is to minimize evaporation losses which change the composition of the fuel and introduce an uncertainty as to the weight of the charge actually burned in the bomb. The error due to change in composition of the gasoline seems to be unavoidable but is of negligible magnitude when dealing with the present types of aviation fuel and is perhaps 0.02 or 0.03 percent for each full percent evaporation loss. The error due to loss of material is in direct proportion to the amount of gasoline that is vaporized.

A simple practical scheme, devised for determining the evaporation loss between the time of completing the final weighing of the filled capsule and the time of closing the bomb, involves determining the rate of evaporation loss (rejecting the capsule if this is excessive) and measuring the time interval between the completion of the weighing and the closing of the bomb. When the initial evaporation loss is not in excess of 0.0010 gram per minute, the rate remains practically constant for at least 2 additional minutes. An experienced operator usually can transfer a capsule from the pan of the balance to the bomb in one minute or less.

Detailed Working Directions

Preparation of Supply of Capsules. Place approximately 1000 gelatin capsules in a bottle with a tight screw top. Allow to stand for at least 30 days to ensure equalization of the moisture content of all individual capsules. In case of emergency, this "soaking" period may be reduced to one week by using an oversize bottle and shaking its contents vigorously at least twice a day.

At the time the soaking period is started, prepare test portions for determination of the calorific value of the gelatin. Each portion consists of about 10 capsules, cut into small pieces and placed inside a capsule. Put these test portions, with the halves of the containing capsules separated, in a small shallow dish or a perforated gill can, which is placed in the bottle with the main supply. At the end of the soaking period, remove the can, assemble the capsules, and place them in a small bottle which is tightly closed. Remove the gelatin-filled capsules from this bottle one at a time for determination of their calorific value. Make at least three determinations, and if the average deviation from the mean of these results exceeds 45 Btu. per pound, make additional determinations until the average deviation is less than this amount.

Transfer at least 100 capsules from the large bottle to a set of small screw-top bottles of similar type, putting 10 to 15 capsules (approximately 2 days' supply) in each bottle. Avoid making the transfer under conditions which might cause the capsules to pick up surface moisture. The relative humidity should not be too high and the capsules should not be far enough below room temperature to bring about condensation.

Filling of Capsules. Withdraw a capsule from the current working supply, restoppering the bottle immediately. Weigh with an accuracy of 0.1 mg. and record as W_1. Pour some of the sample to be tested into a small beaker or crucible. Place each half of the capsule in a suitable brass holder such as is shown in Figure 1. Immerse the halves of the capsule in the gasoline, with the open ends obliquely upward, and agitate very gently for 20 to 30 seconds, to get rid of bubbles of occluded air or other permanent gas which would interfere with complete filling. Then put the two halves together, still keeping them immersed. Withdraw from the liquid, wipe dry with a clean cloth, and place on the pan of the balance.

Weigh to 0.1 mg. and record as W_2. When balance is attained, start a stop watch and obtain another weight exactly 60 seconds later. Record as W_3. Insert the filled capsule in a coil of ignition wire, already attached to the terminals of the bomb and push it down into the cup or crucible. The coil is made by wrapping three or four turns of ignition wire around a rod of the same diameter as the capsules. Care should be taken not to warm the capsule appreciably while transferring from the balance to the coil of ignition wire. If the operator uses bare fingers, they must be dry and his touch must be light. Other precautions, such as the use of special tongs, are obviously permissible. Stop the watch when the lid of the bomb is in place. Do not include the operations of screwing on the lock ring, etc., in the time period thus measured.

Compute the weight of gasoline burned, W_b, from the following formula:

$$W_b = (W_2 - W_1) - (W_2 - W_3)\,\frac{t}{60}$$

t is the time in seconds elapsed between completion of the first weighing of the filled capsule and the closing of the bomb, specifically, it is the stop-watch reading. $(W_2 - W_1)$ is the weight of gasoline originally in the capsule and $(W_2 - W_3)$ the amount lost by evaporation during the 60-second period the filled capsule was kept on the balance pan. A normal figure for this loss is from 0.0001 to 0.0010 gram. If it is as much as 0.0015 gram, or if any bubble of air or vapor is observed in the capsule before the bomb is closed, the capsule is rejected.

Obtaining a weight at some predetermined instant is easy with various types of automatic-reading balances now available. If the simple conventional type of balance is used it is recommended that its sensitivity be determined and that $(W_2 - W_3)$ be measured in terms of change in the swing rather than by trying to shift the rider. It is, however, possible to measure the time for, say, 0.0010-gram loss rather than the loss during 60 seconds. If this is done, the formula above should be suitably modified.

Other Methods for Bomb-Calorimeter Determinations with Volatile Fuels

A somewhat different procedure, using gelatin capsules, has been described by Jones and Starr[4]. It has not been tried in the authors' laboratory but they believe it is slightly less convenient and no more accurate than that described above.

The method of Richter and Jaeschke[7] involves weighing the charge of gasoline in a special platinum crucible covered with a thin skin of collodion. It has not been tried, but the accuracy claimed is no better than that normally attained with the procedure described above.

The most precise method known to the authors is that originally described by Richards and Barry[6], and later improved by Jessup[3] and Prosen and Rossini[5]. The charge is weighed in a hermetically sealed special glass bulb with flattened sides. This bulb, if properly made and completely filled, opens in the bomb without splashing, when exposed to the heat generated by the combustion of the iron fuse wire. The procedure is more time-consuming than that described above and the technique of fabricating, filling, and sealing the bulbs requires a higher degree of manipulative skill than is necessary when using gelatin capsules.

The authors take this opportunity to suggest that the ideal solution of the problem is to weigh the charge in a special closed container which opens mechanically in the bomb when the ignition wire is burned. With adequate ingenuity and experimentation a practical device of this type might be developed.

Precision Attainable

It is customary in the authors' laboratory to make a blank determination once a day on a sample of "chemically pure" benzene. Table 1 shows the results obtained in a period, selected at random, of 29 consecutive working days.

The exact calorific value of the benzene used is not known, hence these "blank" determinations are an index of the reproducibility rather than the absolute accuracy of the determinations. The basic standard is benzoic acid, obtained from and certified by the National Bureau of Standards.

TABLE 1

Benzene Blank Determination for a Typical Period of 29 Consecutive Working Days

(Values in British Thermal Units per Pound)

18,032	18,020	18,005	18,071
18,030	18,031	18,057	18,057
18,011	18,069	18,043	18,039
18,032	18,065	18,048	18,045
18,048	18,034	18,067	18,030
18,041	18,057	18,045	18,033
18,042	18,005	18,060	18,058
18,010			

Mean, 18,041
Av. deviation from mean, 15.5 B.t.u., or 0.086 percent.
Max. deviation from mean, 36 B.t.u., or 0.200 percent.

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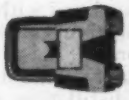

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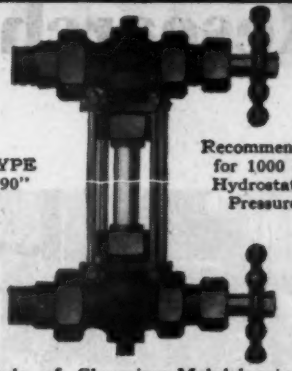

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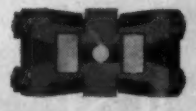

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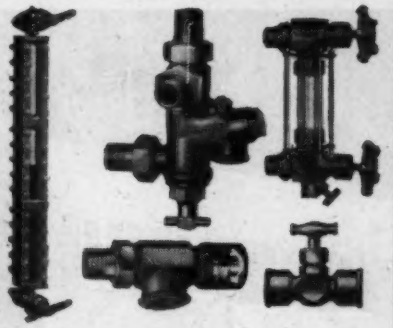

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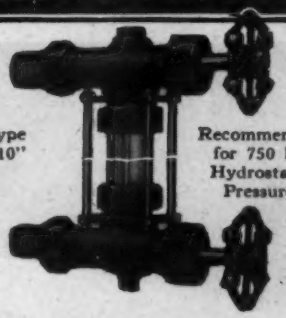

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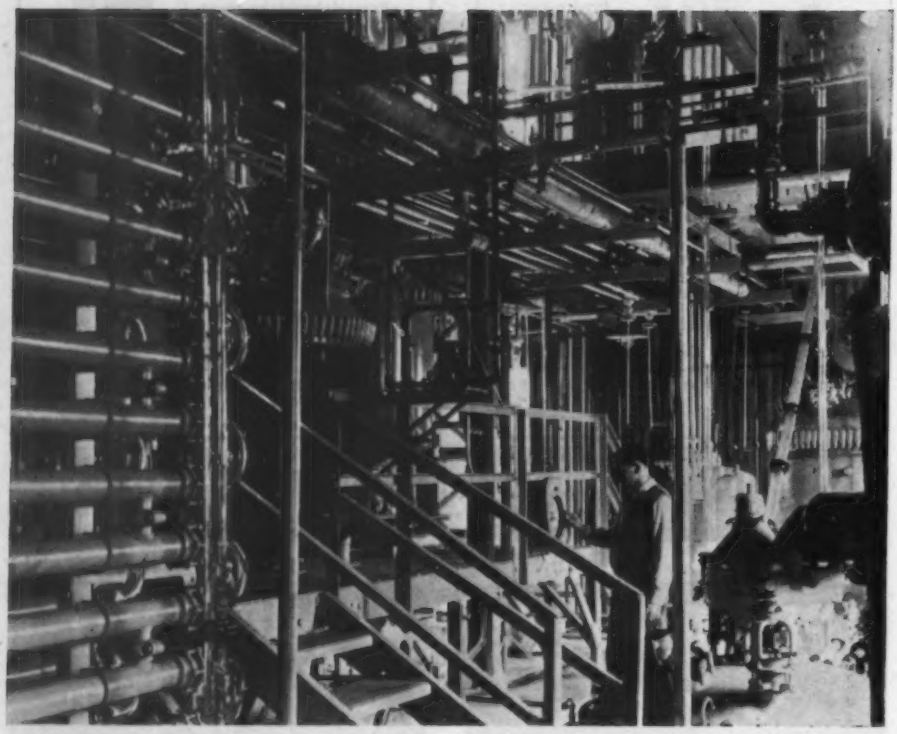
Phillips' New Laboratory Includes Rubber-Research Facilities



PHILLIPS Petroleum Company has recently announced the completion of an extensive rubber polymerization plant at Phillips, Texas. The new unit constitutes another addition to centralized Research Department facilities, which were shown to the public during an Open House on January 5, 1945.

Experimental studies related to the production of better quality polymers are now being conducted by a staff of chemists and chemical engineers, under the supervision of J. E. Troyan, who was recently associated with the Process Development Section of the Office of Rubber Director.

The pilot plant contains diversified equipment for distillation and purification of monomers, polymerizers, a coagulation unit, and filtration and drying equipment. Here it will be possible to produce sufficient rubber for full-scale processing and tire tests. Auxiliary refregeration equipment, a small-scale polymerization unit, and raw-material storage space are located in an adjaecnt one-story buiding.

A distinctive feature of the Phillips pilot plant design is the use of glass-lined vessels and glass piping at all points in the process where it is desired to prevent contamination of the latex and chemicals handled.

Main laboratory of Phillips Petroleum Company's new research facilities at Phillips, Texas. In addition to this building, which covers approximately 13,000 square feet of space, the plant includes a lead-blending plant, a pure-hydrocarbon manufacturing plant, a warehouse, and three pilot plants for development of synthetic-rubber polymerization, carbon black, and other products. Generally speaking, these laboratory facilities will be devoted to the pilot-plant or development phases of the company's research. The picture at top shows the interior of the rubber-polymerization pilot plant.

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Cooperation Required in Accident Prevention

OTTO PETERS, SR.

INDUSTRIAL accident prevention requires cooperation from three basic factors, management, supervisory force, and the worker. It is an established fact that forceful executive direction is most essential to bring about top safety performance. This executive leadership will provide for management attitude, the set-up of safe practices, the enforcement of penalty for rules violations, and an organized program for safety training and teaching. In industry the supervisory force (the foreman) is looked upon as the key-man for safety, because due to his knowledge, skill, influence, and close association with men under his supervision, he is in the position to transmit the rulings of the management to the worker. For the worker himself, management and supervisory force have in their teaching of safety made all efforts to obtain his support in the protection of company interests as well as to strive for his own welfare.

There should be no sentiment attached to the efforts to prevent accidents. It is far better to take an attitude of intolerance toward accidents because accident prevention is definitely a dollar-and-cents proposition, and employes who through their own carelessness or willful rules violations bring about accidents resulting in injury to themselves or to those with whom they work, are imposing an uncalled-for expense on their employer.

Cost to Management

The interest of management may be aroused and its support obtained, when it is convinced of the 4-to-1 ratio of accidents costs as outlined in Heinrich's book on Industrial Accident Prevention. Most certainly an employer will be startled to realize that the costs of accidents that he sees, (exclusive of compensation and hospitalization) is only one fifth of the total cost. Another startling revelation will be in the realization that great savings and profits can be obtained in compensation insurance costs due to reduction in accident frequency and severity, as well as by proper distribution of employe classification. It is an obligation on those charged with the responsibility of accident prevention to see to it that management is made aware of these possible savings, and also made aware that a safety program will not be successful without executive leadership.

Accidents are preventable. The plain truth of the matter is that men hurt themselves or are hurt by those with whom they work. To convince yourself of this, check the accident report against the factors man-tool-method. The term carelessness as the cause for accidents should be discontinued, as there is a deeper, more tangible reason. It is failure to observe safe practices under any and all working and seasonable conditions. The word carelessness in the studied causes for accidents is not mentioned, nor will you find it used in any listing of accident causes. Safety consciousness is a habit that can only be acquired by the constant practice of the safe way of doing things, the exercise of forethought in recognizing accident hazards, and the knowledge of how to prevent and how to eliminate them.

The National Safety Council in one of its recent publications stated that "every 5 minutes there is 1 death and 92 injured due to accidents, and that accidents have in effect, reduced 350,000 active war time workers to industrial 4-F." The loss of life, the disabilities, the economic losses due to accident have reached such staggering totals that we may assume it to be a national menace to the welfare of our country. I am of the opinion that to further stimulate the interest of the worker and to obtain his continued efforts toward accident prevention, it may be well to make him aware of the costs to him when he meets with accidental death or disability, and to this end I submit "Summary of Fixed Compensation for Incapacity Resulting From Specific Injuries," taken from Texas Civil Statutes, Article 8306, Sections 8-10-11a and 12, in the hope that the evident result of momentary forgetfullness will leave a permanent impression upon the reader.

Texas Compensation

For the injuries enumerated in the following schedule the employe shall receive in lieu of all other compensation except medical aid, hospital services and medicines, as elsewhere herein provided, a weekly compensation equal to 60 percent of the weekly wages of such employe, but not less than $7.00 per week nor exceeding $20.00 per week for the respective periods stated herein, to-wit:

Compensatable Injuries	Weekly Compensation
Death	360
For the loss of a thumb	60
For the loss of a finger	45
For the loss of a second finger	30
For the loss of a third finger	21
For the loss of a fourth finger (little)	15
For the loss of a hand	150
For the loss of an arm, at or above elbow	200
For the loss of one of the toes other than the great toe	10
For the loss of the great toe	30
For the loss of a foot	125
For the loss of a leg at or above the knee	200
For the total and permanent loss of the sight of one eye	100
For the Complete and permanent loss of hearing in both ears	150
For the loss of an eye and leg above the knee	350
For the loss of an eye and an arm above the elbow	350
For the loss of an eye and hand	325
For the loss of an eye and foot	300
Injuries constituting total and permanent disability	401

This summary represents the irreplaceable loss of parts of the human body for which the law provides a minimum and maximum payment for a limited number of weeks. Keep in mind the amount of payment is determined by your weekly wage as established for one year prior to the date of accident. The human body is endowed with a brain which is supposed to be used and exercised in the prevention of injury, or loss, of any part of the human body. Do not fool yourself into thinking that you will be able to work as efficiently as if you had not lost any of these parts. In your competition to earn a livelihood, you will realize all too soon that your handicaps are increased through body impairment. Think also of the suffering of pain, the monetary loss, the anxiety of dependents, the accrued hardships due to disability brought about by accident resulting in injury to your person. You say these accidents are due to carelessness—then are you going to be careless enough to sell your arm, or your legs, or your eyes for any sum allotted by law? If you want to play fair with yourself, your dependents and your employer, then you have every reason to help eliminate the cause for accidents.

Compensation starts the eighth day after the incapacity. If the incapacity is for four weeks or longer, then the compensation will be computed from the first day instead of the eighth day. The actual payment for compensation is made about two weeks after the beginning of the incapacity and is made for one week. When the incapacity passes the fourth week, then an extra week is included which covers the first week's incapacity. This brings to mind the importance of prompt report of accidents.

Minimum and maximum values had to be set to protect the employe who drew small wages and to protect the insurance carrier of the employer in the case of high-salaried employes whose services would be lost during the time of incapacity in addition to the cost of compensation. Then, too, if there was no limit on the compensation, there could be no limit on the insurance rate. It may rightly be assumed that the law makers of that time placed a minimum of $7.00 per week and a maximum of $20.00 per week to assure at least $1.00 a day, and $20 weekly as being sufficient to meet the economic need of that time.

Compensation Suits

For a compensation case not involved in law-suit, a lump sum settlement for the total permanent incapacity may be effected under the Workmen's Compensation Act of Texas, by what is known as the Compromise Settlement Agreement. When approved by the Industrial Accident Board, the compromise agreement is paid.

For a compensation case involved in law-suit, it may be noted that the Texas Workmen's Compensation Act states that an attorney representing an injured employe receives 15 percent of the first $1,000 in the event a case is compromised before it reaches suit, and in the event a suit is necessary and filed by the attorney, he shall receive 33 1/3 percent of any amount recovered.

I do not know what causes one to bring suit for compensation payment. The salary has stopped for the one incapacitated, the need for money is urgent, a lump sum settlement appears more desirable than weekly payments. There may be anger and resentment against employer, there may be unscrupulous influences at work, whatever the reason, let me tell you to avoid suit if at all possible. In my 30 years of work as a salaried employe I have always found employers ready and most anxious to help an injured employe to obtain full and adequate justice in all compensation cases. In all fairness to lawyers I may do no harm in reminding you that the matter of 33 1/3 percent is something for you to think about. It is not wise to bring suit until after you have presented your case to the Industrial Accident Board, as the proper forms for filing any type of claim will be furnished by the Industrial Accident Board direct to the employe without the necessity of having some third party present the case to the board.

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One Refinery Worker's Observations On Industrial Relations

HOWARD W. LARSEN

THERE are many terms and phrases that are used altogether too glibly by our radio and press. Foremost among these vague expressions is the term "labor problem". Continually we hear references to the labor problem as one of our chief postwar problems. And yet the question may easily be asked, "What is our labor problem?" A satisfactory answer to this query is not readily received.

The petroleum industry has not been plagued with labor disturbances to the degree that other industries have been hampered. To a large extent this may be attributed to the progressive attitude taken by management. The industry is fairly young and management, profiting by the experiences of older industries, has been quick to remedy any unfavorable conditions that disturbed pleasant employe-employer relations.

However the agreeable relations between management and labor in this industry has produced another effect; there is a vast indifference among petroleum men of the problems facing American labor in general. Indeed, there is a tendency to condemn labor unfairly when speaking of the labor disturbances in other industries since we are not at all well acquainted with the many factors that contribute to a labor problem. It may be well then for us to consider some of these factors briefly.

The labor problem is the accumulation of many unfavorable conditions in American life experienced by the vast majority of the American people. It is altogether impossible to enumerate all of these conditions, however, the more important may be listed as follows:

Unemployment.
Wage grievance.
Hour grievance.
Industrial accidents.
Industrial illnesses.
Sub-standard workers.
Superannuated workers.
Industrial autocracy.

It may be well to explain that the above conditions are not listed in the order of their importance. Although unemployment is clearly the greatest disease of our democratic system, many difficulties would soon be encountered should an attempt be made to determine the relative importance of the remaining seven conditions. A discussion of each one will quickly reveal the peculiar place each has in contributing to what we call "the labor problem."

Unemployment

American labor is not as much disturbed about the "irregular" causes of unemployment as it is about the "regular" causes. Irregular causes such as unpredictable weather which affects farmers, changes in fashion which concern our garment workers, and changes in foreign markets which affect workers in the export industries, are difficult to govern, and labor sympathizes with management as it attempts to cope with these conditions. However, such regular causes as technological unemployment, seasonal employment, and business cycles can have their impact on labor softened and this is what American labor wants. Technological unemployment would not be such a major grievance if the workers to be released by the installation of a new machine were given sufficient warning to seek a new job. Seasonal employment may in many industries be avoided by fair and wise planning on the part of management. Unemployment caused by a downward surge in the business cycle can be decreased by sufficient economic research to guard against overproduction or underconsumption of certain commodities and scientific research to open new fields of production. Unemployment cannot be eliminated but it can be decreased. The insecurity resulting from the prospect of unemployment is American labor's major grievance.

THIS article is being printed in the hope of promoting better understanding. Consideration of what the "other side" proposes is one approach to understanding. Without understanding, bickering between conflicting elements within industry will grow more intense.

With many of the author's observations Petroleum Refiner is not in accord. Difference of opinion, however, does not justify refusal to consider. If it is not a duty, at least it is a privilege to offer an outline of what men who work in refining plants consider their rights.

Briefly, the attitude of Petroleum Refiner is that such terms as "labor" and "management" have so many common objectives that it is unfortunate that the words have come to have restrictive meaning. Each wants the same thing from business. One calls it wages; the other calls it dividends. Neither can be provided except through profits.

When this attitude was outlined to the author, he expressed appreciation and asked that the observations be singled out as his own and not necessarily those of Sun Oil Company, by which he is employed as a chemical engineer in its Toledo plant.

Wage Grievance

There are two kinds of wages which are of major concern to labor, money wages and real wages. A money wage is the monetary remuneration which an employer pays an employe for his services. A real wage is the relative value of the money as a purchasing power. It determines what a worker is actually paid for his services, for if a pair of shoes cost five dollars one year and ten dollars a decade later, an employe's real wage has been halved even though his money wage may have remained the same. There is always a lag in real wages behind money wages. American labor wants greater effort on the part of management to diminish the gap between the two.

Secondly, labor wants a fair evaluation of the relative value of the different kinds of services and wants this relation maintained. That is to say, if a refinery operator is worth more on an hourly rate than a helper, he wants to be paid more and wants the ratio between the two rates maintained fairly, even during times when economic conditions call for a readjustment of rates.

Hours Grievance

The industrial revolution and the accompanying development of specialization in industry brought about a great change in the attitude of workers. Before this industrial shake-up, workers took a personal interest in their work and did not complain about long hours. They were craftsmen who had great pride in their finished product and who were spurred on by the possibility that some day they could go into business for themselves. With the industrial revolution, men became mere cogs in the wheels. In doing the same small routine job every day fatigue readily set in and labor needed more time for rest. Then again, the higher standard of living that developed opened up new facilities and opportunities for spending leisure time. Labor wanted more time to enjoy the fruits of its efforts. After years of fighting for shorter hours, the establishment of a 40-hour week, several years back, was labor's crowning achievement. When normal times once again return, American labor is looking forward to the re-establishment and maintenance of a short work week allowing sufficient time for rest and leisure.

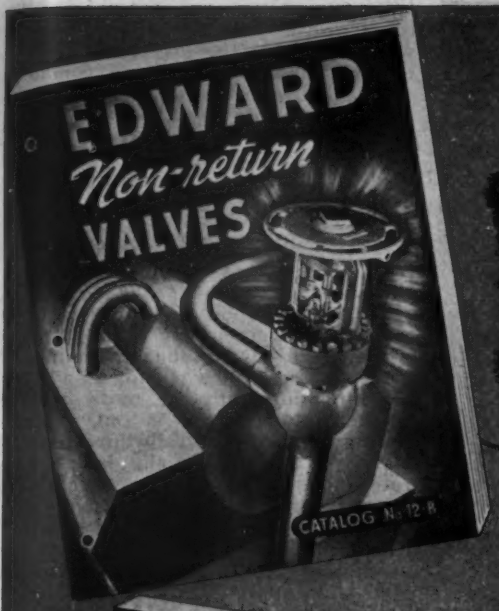
Industrial Accidents

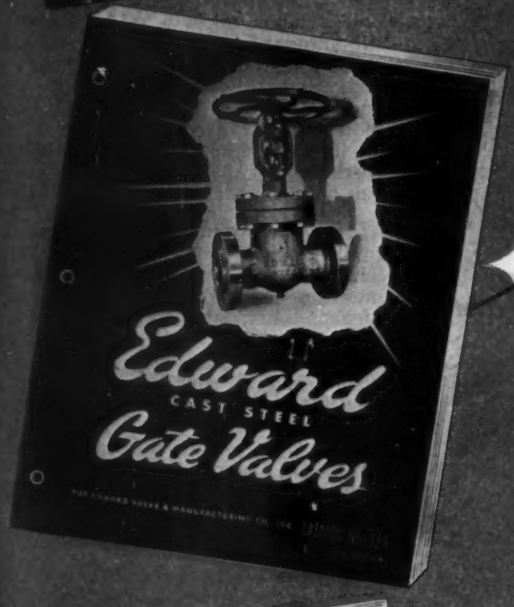
There are two chief causes of industrial accidents, mechanical causes and human causes. Mechanical causes have been and are being rapidly reduced by the use of guards where safety demands. Not only has this proven profitable to labor but management also realizes the value of protecting its workers and has cooperated wonderfully to reduce this danger. However there are some employers who have not been so enlightened and labor must ever be vigilant to protect its members.

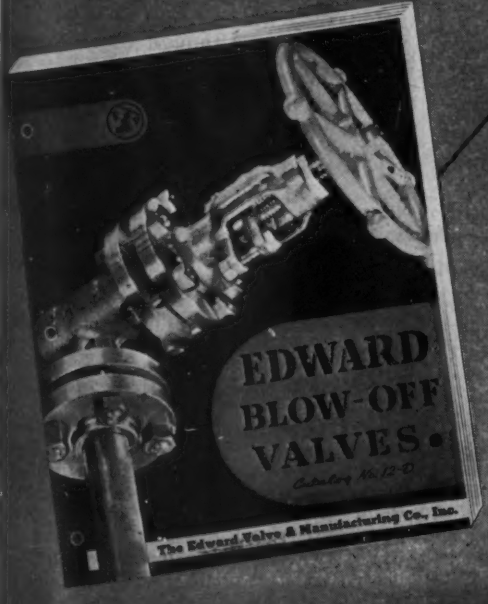
The human causes of industrial accidents are difficult to reduce. Man is ill-adapted to a machine and speed, monotony and noise all contribute to fatigue and the resulting accidents. Then again, men feel a sense of immunity from danger after they have repeated the same operation over and over again without injury. This over-confidence is hard to combat, however a reduction in the other contributing factors may be facilitated and labor is continually wary to note these factors and suggest means of improvement.

Industrial Illnesses

Illnesses which are the result of continuous exposure to harmful working conditions and which result in disability or death are a very real threat to labor. For example, some industries develop atmospheres which would tend to promote respiratory diseases. Others perhaps reduce skin infections and in







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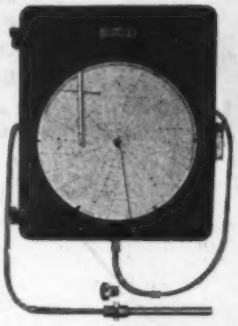

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still others improper lighting or the constant use of the same body members would result in the loss of eyesight or cramps. Unhealthy working conditions of the above nature continually are a major grievance of labor. Only by a sustained effort on the part of labor organizations has improvement been made. Labor wants a healthy working environment.

Sub-Standard Workers

In a democracy during normal times there are more men than jobs. This stimulates competition and the better men receive employment. The inferior worker will then reduce the minimum wage that he will work for as a means of competing with the more qualified worker. Management is out to make profits and will naturally hire the sub-standard workers at the lower wage rate unless it feels that the quality and quantity of the work produced by the more skilled worker will compensate for the higher wage rate. Unfortunately as more machinery is introduced, less skill is required. The net result is that unless labor takes a stand against the sub-standard workers, the downward spiral will continue. American labor feels that the employment of women and children in industry and the exploitation of the many ignorant workers in this country who are willing to work for "scab" wages is unethical and can only be combated by a united stand.

Superannuated Workers

The insecurity of old age is a problem of labor. As has been previously mentioned, fatigue is one of the results of the industrial set-up and has led to an early aging of workers. It can be safely stated that whereas men are not discharged at the age of 40, the difficulties in securing employment have been immeasurably increased. Management wants youth, for unless the task calls for a particularly skilled artisan, youth has the capacity to yield a greater output. Management is certainly justified in hiring young men in preference to older men for they are investing money and are competing for profits. However such a system hardly contributes to the security that labor so dearly wants. Although most business organizations do keep their older employes on the job, labor must wage a continuous fight against those employers who discharge workers because their productivity has been curtailed by superannuation.

Industrial Autocracy

A strange phenomenon in industrial relations will now be considered. It may be possible to correct everyone of the grievances of labor and still have discontented employes. The reason is that unless labor has some voice in management, satisfaction will not be in order. Progressive employers have dealt with this situation by requesting their employes to select representatives to present their views to management. Among workers who are not affiliated with any organized unions, employe associations have been encouraged and in many cases have functioned satisfactorily. As opposed to these progressive employers there are still a few left of the old school who insist on autocratic control and continually suppress the democratic spirit of their employes. Labor must present a united front to these autocrats as a token of its disapproval, ever looking ahead to the day when all

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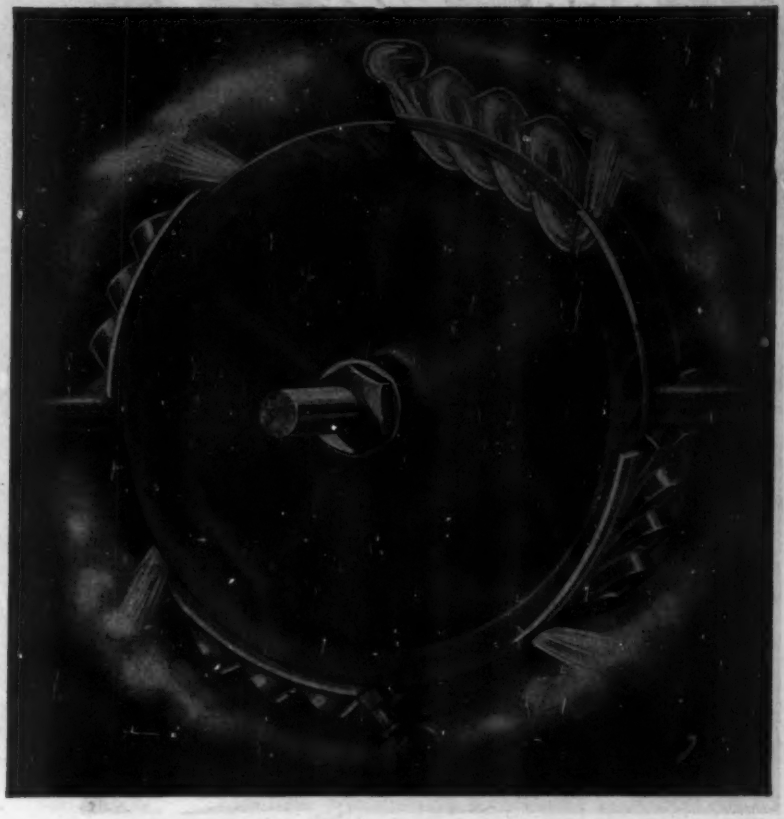

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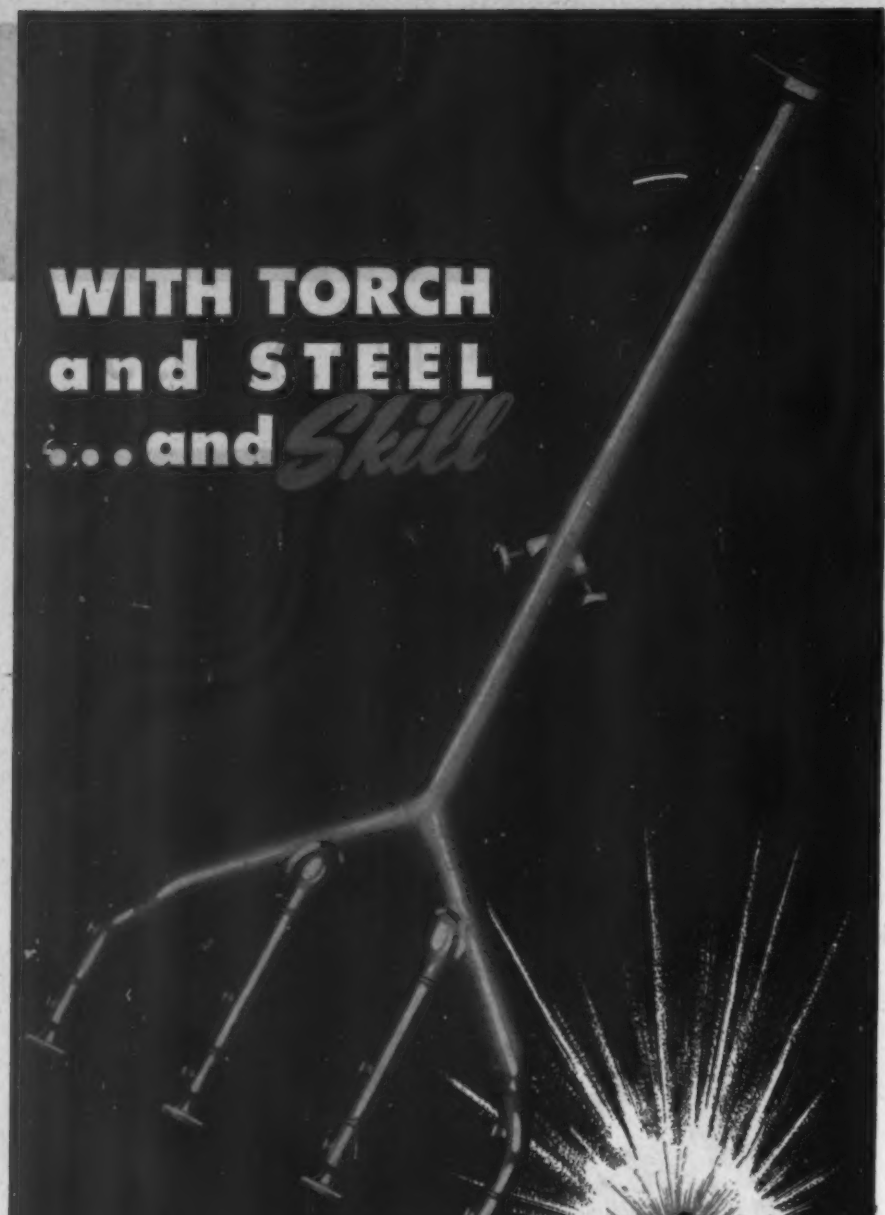

One of the important factors in the development of modern science and industry is industrial piping. Keeping pace with the conceptions and requirements of engineering has been the responsibility of fabricators. Since pipe fabrication is our business, we of Associated have constantly studied and striven in the improvement of techniques and procedures. With torch, steel and skill, and use of finest equipment this firm goes forward... We would like to help with your piping requirements.

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employers will see the advantage of meeting with their employes for the purpose of exchanging ideas.

* * *

An attempt has been made to briefly examine the major conditions which contribute to the present labor problem. It may be possible to correct all but one of these grievances and still be faced with discontentment among workers. The possibility also exists that even if the remaining grievance were removed, another one would bheak out. The labor problem is continuous and can never be entirely solved. However it can be relieved by more strenuous and honest efforts on the part of labor and management to understand each other. We of the petroleum industry can be extremely thankful that for the most part our employe-employer relationships have been cordial and in most cases have brought the desired results. We are looking forward to the day when the same thing can be said for not only our entire industry but also for the other industries in our nation.

Baton Rouge Employes-Medical Building Opened

Standard Oil Company of New Jersey's Louisiana Division dedicated an elaborate new employe-relations and medical building at Baton Rouge refinery on February 2. Ceremonies in which officials of the company and prominent visitors took part were held on two days. The building provides ample facilities for emergency hospitalization and health protection, and provides many comforts for employes.

Thiophene from Petroleum Available at Lower Cost

Socony-Vacuum Oil Company has announced development of a process for producing thiophene from petroleum which makes this product commercially available. Production of the chemical is underway in a laboratory pilot plant, and a plant under construction will have capacity of several barrels per day. Previously thiophene has been produced by synthesis from coal tar at a cost of about $54 a pound, too expensive for its use in many phases of chemical industry where its value is demonstrated.

Thiophene is a colorless liquid, C_4H_4S, containing 57.1 percent carbon, 4.8 percent hydrogen, and 38.1 percent sulphur. Its structure is agreed to consist of a five-membered ring containing four carbon atoms and one sulphur atom. The ring contains two double bonds between two of the pairs of carbon atoms. One hydrogen atom is connected to each carbon atom. In its reactions thiophene resembles benzene, although different reaction conditions may be necesary. Substitution of the thiophene ring for the conventional six-carbon-atom benzene ring presents numerous opportunities for altering the characteristics of many products, such as the color of dyestuffs, physiological effects of medicinals, and hardness, elasticity, brittleness and other properties of plastics.

Under suitable reaction conditions, thiophene also reacts with aldehydes, particularly formaldehyde, to form thermoplastic resins. In this respect the behavior of thiophene may be likened to that of phenol in the preparation of thermosetting resins of the phenol-formaldehyde type, although there are important differences.

United Nations Refineries Keep Busy in War Effort

With few exceptions, all refineries of the United Nations, are operating at maximum capacity, it was announced February 27 by PAW.

In addition to the large output of American refineries and the undisclosed production of those in the Soviet Union, 66 refineries in 22 United Nations processed 1,450,000 barrels of products daily in 1944, it was reported.

Shortages of tankers and the long hauls involved made it impossible to take full advantage of the potentialities of these plants in the early days of the war, but within the last two years the building up of the tanker fleets has enabled use of foreign oil production and refining facilities virtually at maximum capacity, the report said.

The few foreign refineries that are not operating at maximum capacity are those that are undergoing repairs from bombing damage, those that cannot be supplied with crude or whose products cannot be moved.

Much of the operation of overseas refineries has been carried on despite problems ranging all the way from shortages of food and drinking water to attacks by enemy bombers and submarines.

Material and food-supply problems have been complicated by shipping difficulties beyond the normal expectation of wartime conditions, and furloughs of personnel to the United States and England have been prohibited, some of the men not having seen their families since before the outbreak of the war.

API Report Shows Crude Oil Reserves Increased

Despite production of substantially larger quantities of crude oil than in any previous year, and drilling far below normal, the oil industry in the United States found more oil than was consumed in 1944, it was revealed in the annual report of the American Petroleum Institute's committee on petroleum reserves. The estimate of proved reserves at the end of the year was 20,453,231,000 barrels; at the end of 1943 this figure was 20,065,152,000 barrels, the difference of 2,067,500,000 barrels representing new oil discovered during the year. Production during the year was shown at 1,678,421,000 barrels, which means that the net increase of reserves during 1944 was 389,079,000 barrels.

Since Pearl Harbor, the United States has found within its borders nearly a billion barrels more oil than has been used in that period.

Upward revision of figures in fields previously discovered accounts for 1,556,000,000 barrels of the reserves added in 1944, which indicates that the 511,000,000 barrels added by new and little drilled fields is conservative.

Development during the year increased Mississippi reserves 170,139,000 to 209,011,000; Louisiana increased 89,561,000 to 1,573,387,000 barrels; Wyoming increased 82,336,000 to 581,730,000 barrels; Oklahoma increased 61,644,000 to 970,262,000, and while Texas increased only 50,526,000 barrels its reserves of 11,375,480,000 barrels still is well over half of the total for the United States. California, despite the extra effort to get out more oil, increased 7,729,000 barrels, to 3,344,552,000 barrels.

Seek $100,000 to Finance Gas Reserve Investigation

Plea for an appropriation of $100,000 to finance a Federal Power Commission investigation of the natural gas reserves of the country was made before the Senate appropriations committee March 2 by Senator John H. Overton of Louisiana.

Overton said use of natural gas for indsutrial purposes is so tremendous that many fields will be exhausted in a comparatively short period. He cited as an example of the extent of the depletion that the Monroe field in Louisiana at the present rate of withdrawal has only a seven-year supply.

Members of the committee were interested in Overton's presentation but decided to withhold action until the matter has been submitted to the budget bureau and passed upon by that agency.

Meanwhile the Federal Power Commission announced receipt of a third application for a major facility to supply the Middle West with additional gas, filed by the Metropolitan Eastern Corporation for construction of an 825-mile 18-inch line from East Texas to Ohio.

Postwar Monopolies Would Be Prevented by New Bill

Legislation designed to prevent monopolies, strengthening a 30-year federal prohibition against monopolistic mergers, has been introduced in Congress by Senator Joseph C. O'Mahoney of Wyoming and Representative Estes Kefauver of Tennessee.

The measure would prohibit a corporation from acquiring the physical assets of another corporation where the effect of such acquisition would be to "substantially lessen" competition.

The existing law prohibits a corporation from acquiring another by purchase of its capital stock, where such action would reduce competition, but is declared by O'Mahoney and Kefauver to have left a loophole whereby a corporation can move toward monopoly by the acquisition of the property of competing corporations.

"Now that the country must begin to prepare for the postwar world, it must decide whether to maintain a free economy by maintaining a competitive system or, by permitting the trend toward monopoly to continue, invite the final step in monopoly, namely the complete absorption of business in government," they said in a joint statement. "It will be our intention to ask for early consideration of this legislation in the belief that it constitutes a first step in the rehabilitation of a free competitive economy in which little business can hope to survive."

Inbound and Outbound Oil For 1944 Show Large Gain

Shipments and receipts of bulk petroleum cargo in United States ports, excluding United States military cargo, approximated 30,000,000 tons in 1944, it was reported by the War Shipping Administration.

Liquid cargo carried inbound and outbound during the year exceeded the total carried in 1943 by more than 55 percent, with outbound shipments alone averaging 1,750,000 tons monthly.

The Maritime Commission's long-range building program began with deliveries early in 1939 of the high speed national defense type tankers that were

Crude Oil Runs to Stills, Production of Refined Products, and Stocks for the Four-Week Period Ending February 24, 1945

(Figures, in thousands of barrels of 42 U. S. gallons each, based on reports of American Petroleum Institute. Production and stocks include reported totals plus estimated amounts to make these figures on a Bureau of Mines basis)

DISTRICT	Capacity Percent Reporting	Crude Runs to Stills: Daily Average	Crude Runs to Stills: Percent Operating	Production: Gasoline*	Production: Kerosine	Production: Gasoil and Dist. Fuel Oil	Production: Residual Fuel Oil	Stocks at Refineries, Terminals and in Pipe Lines: Finish and Unfinished Gasoline	Stocks at Refineries, Terminals and in Pipe Lines: Kerosine	Stocks at Refineries, Terminals and in Pipe Lines: Gasoil and Dist. Fuel Oil	Stocks at Refineries, Terminals and in Pipe Lines: Residual Fuel Oil	Crude Oil: Daily Average Production	Crude Oil: Stocks†
East Coast	100.0	720	99.5	7,542	755	4,068	6,673	13,349	2,121	5,469	4,926	.....	.....
Appalachian District 1	83.9	99	75.9	1,229	241	294	427	2,612	361	339	228	.....	.....
Appalachian District 2	87.2	60	127.7	758	54	210	373	1,638	57	167	205	.....	.....
Illinois, Indiana, Kentucky	85.2	728	95.4	11,740	1,031	2,631	4,637	22,942	1,564	3,741	2,336	.....	.....
Oklahoma, Kansas, Missouri	80.2	367	90.6	5,542	638	1,638	2,076	9,447	466	1,743	1,174	.....	.....
Inland Texas	66.9	240	86.2	3,841	370	491	1,845	3,091	131	381	656	.....	.....
Texas Gulf Coast	90.5	1,170	100.4	14,377	1,675	5,787	7,922	15,836	1,221	5,418	8,021	.....	.....
Louisiana Gulf Coast	95.5	259	106.9	3,395	822	1,135	1,184	5,120	910	1,859	1,442	.....	.....
North Louisiana, Arkansas	68.0	81	78.1	898	213	246	492	3,057	152	757	271	.....	.....
Rocky Mountain District 1	17.0	11	82.7	142	16	32	95	86	15	15	28	.....	.....
Rocky Mounatin District 2	58.3	102	71.6	1,494	90	236	797	2,152	100	315	580	.....	.....
California	89.9	845	103.7	8,983	201	2,367	10,375	16,651	416	8,549	26,856	.....	.....
Total U. S. February 24, 1945	87.2	4,755	96.8	59,941	6,106	19,135	36,932	95,972	7,514	28,753	46,723	4,752	220,060‡
Total U. S. January 27, 1945	87.2	4,756	96.9	.....	.....	.....	.....	89,223	9,481	33,651	51,119	4,727	237,511
Total U. S. February 26, 1944	.....	.....	.....	.....	.....	.....	.....	81,604	8,187	36,333	52,956	4,423	237,137

*Includes natural gasoline blended at refineries. †Bureau of Mines. ‡February 17, 1945.

the mainstay of the tanker fleet when we entered the war. Since that time, 640 tankers of 9,374,000 deadweight tons have been put into service by Maritime Commission construction, the figure including ocean, inland and military types.

Five 100-Octane Plants Given PAW Approval

Five new plants have been scheduled for construction, and several more are under consideration, it has been announced officially by the Petroleum Administration for War, in a new expansion of the 100-octane-gasoline program. It was revealed that very substantial increases in 100-octane-gasoline production have been asked by the armed forces, although production has been above 500,000 barrels daily since last October.

The new plants scheduled are to cost $78,000,000, financed privately. Shell Oil Company will build a plant at Houston; Standard Oil Company (Indiana) two, at Whiting, Indiana, and Sugar Creek, Missouri; The Texas Company at Lockport, Illinois, and Leonard Refineries, Inc., at Alma, Michigan.

It was pointed out that the supply of high-octane gasoline recently has been getting some aid from the rubber plants, but this source of cumene for gasoline blending is soon to be cut off as the rubber program takes up expected expansion.

Natural Gasoline Plants Authorized for California

Extensive construction activity in the natural gasoline industry in California is indicated by projects approved by the War Production Board, acting on the recommendation of the natural gas and gasoline division of PAW.

General Petroleum Corporation has been given approval for construction of a natural gasoline plant in Fresno County, to use product from the Helm and Riverdale fields, to cost between $1,000,000 and $1,250,000. Barnsdall Oil Company has obtained approval for building a pressure-maintenance plant in the Newhall-Potero area north of Los Angeles in Los Angeles County, at a cost of $500,000.

Standard Oil Company of California will build a pressure-maintenance plant for the Navy in the Elk Hills reserve at a cost of about $250,000.

Doheny, Los Neitos, Seaboard, Honolulu, et al, have been given approval for a $500,000 natural-gasoline plant in the Coalinga Nose oil field in Fresno County.

Consumers Cooperative Buys Texas Refinery

Consumers Cooperative Refinery Association, representing farmers cooperative associations in Texas, Oklahoma and New Mexico, has purchased Motor Fuels Corporation's 5000-barrel skimming and cracking plant at Levelland, Texas, for reported consideration of $750,000. The plant has been operating since 1939, processing crude oil from the Slaughter field. Officers of the association include H. H. Hogue, Dalhart, president; R. B. Gist, Happy, vice president, and W. W. Kurfees, Plainview, secretary. Leonard F. Cowden, general manager of Consumers Cooperatives Associated, is treasurer and general manager, and Joe Denton, Jr., was retained as plant superintendent.

Government to Build Shale Plant in Colorado

The Bureau of Mines has selected a site on Navy oil-shale reserves in Western Colorado for a $1,500,000 oil-shale demonstration plant to be constructed under the synthetic liquid fuels act. The plant will be built on government-owned land in the Anvil Points area, seven miles west of Rifle. Major points of the plant will include a 200-ton-a-day shale mine, a 1½-mile aerial tramway to carry the shale to the plant, and crushing and retorting equipment adequate to provide useful information on operations and costs. A shale-oil refinery of pilot-plant scale will be added later when the technical information needed for its design is obtained by a laboratory which is to be built at Laramie, Wyoming.

Selection of the Rifle and Laramie sites puts essential parts of the five-year synthetic liquid-fuels program in operation, on both coal and shale sources. Bureau of Mines technicians, it was revealed, now are overseas examining recently captured German plants which made liquid fuel from coal, and a laboratory for study of fuel from coal is under construction at Bruceton, Pennsylvania. Site for a demonstration plant to make liquid fuels from coal is yet to be selected.

From 1925 to 1929, the Bureau of Mines operated an experimental oil-shale mine and retorting plant near Rulison, Colorado, three miles west of the new demonstration plant site, and a laboratory-scale shale-oil refinery at the University of Colorado at Boulder. Bureau technologists mined and retorted approximately 6000 tons of oil shale, and produced 3600 barrels of oil. No commercial-scale production was attempted at that time, and the information obtained was inadequate to estimate economic possibilities.

Jet Airplane Motor Gives More Power and Speed

Information made public with approval of the War Department reveals an improvement in the jet airplane motor, which is credited with more power and higher speed than any other engines. The new jet motor is driving the Lockheed P-80 fighters, Shooting Star.

A description of the motor and its operating method from General Electric Company is to the effect that a new motor is superior to the first one built by that organization and "far more powerful than any conventional reciprocating engine for aircraft." Operation of the engine is thus described:

"Air to the jet engine in the P-80 rams into vents in the front of the wings, almost flush against the fuselage. It pours through the vents to the engine, where it is compressed by a swiftly revolving impeller. At extremely high altitudes the air will be as cold as 75 degrees below zero. The air is whipped by the impeller to a combustion chamber, where fuel (usually kerosine) burns fiercely. This causes the air to expand and increases its velocity. The air and gases then pass through a blazing-hot turbine wheel, which is connected by shaft with the impeller. The blast then passes out the jet exhaust at the rear tip of the plane, giving the drive or forward thrust.

"This reactive thrust, which drives the Shooting Star and other jet planes forward, is so simple that it sometimes is hard to understand. It conforms with Newton's third law of motion: that to any action there is an equal and opposite reaction. A simple example is a garden spray of the spinner type, which revolves in the opposite direction from which the spray streams go.

"This new jet engine makes virtually no vibration, lessening fatigue for the pilot. It is simple to maintain, having few movable parts. Pilots of a P-80 hear no noise from the jet while in flight. The rumbling roar from it passes out the rear.

"Another outstanding performance characteristic of the P-80 is its high altitude maneuverability. The G-E jet functions powerfully and smoothly at extremely high altitudes. Due to less air drag on the plane, the jet uses much less fuel at high altitude than it does going at the same speed at low altitude.

"Another advantage of this new super jet engine is that it requires no warm up. It develops more than enough power for a take-off in less than a minute."

Special fuels and lubricants for turbo-jet engines, motive power of jet-propelled fighter aircraft, have been developed and are being supplied by The Texas Company. Announcement of this was made in conjunction with the release of details on the engine itself.

Contrary to reports, some unusual problems have been encountered in fueling and lubricating the jet engine. Fuel requirements are quite different from those of the conventional aircraft engine or the diesel. The fuel is a very narrow petroleum "cut" somewhere between kerosine and gasoline in nature. The lubricant must perform satisfactorily under severe extremes of temperature. It must flow freely at 80 to 90 degrees below zero, Fahrenheit, and yet must retain its lubricating properties and not break down in high speed bearings at 250 degrees above. Fuels and lubricants developed by The Texas Company are undergoing extensive tests in Army jet planes.

Lead and Tire Shortages Make Auto Outlook Gloomy

Owners of automobiles, trucks and busses are facing the toughest period of the war, with 1,500,000 more passenger cars due to break down during the year, gasoline and tire supplies remaining critically short, and the serious shortage of lead necessitating greater conservation of batteries, the Office of War Information has warned in a review of the automotive situation.

Highlights of the situation were summarized by OWI as follows:

Gasoline: Although production of all types of gasoline is at record level and every effort will be made to increase production, civilian supplies at best will continue unchanged during 1945 or for the duration of the European war, "provided military demands for gasoline and petroleum products are not increased and the transportation problem does not become more critical." Consumption of gasoline during the fourth quarter of 1944 exceeded allocations, thereby reducing the Nation's reserves.

Tires: Production of synthetic rubber in 1945 is currently scheduled at more than 1,000,000 long tons; military requirements for heavy duty tires have jumped 30 percent; tires for civilian trucks and busses will be short, probably available to Priority I vehicles only; B and C drivers may anticipate stringent screening of needs and the

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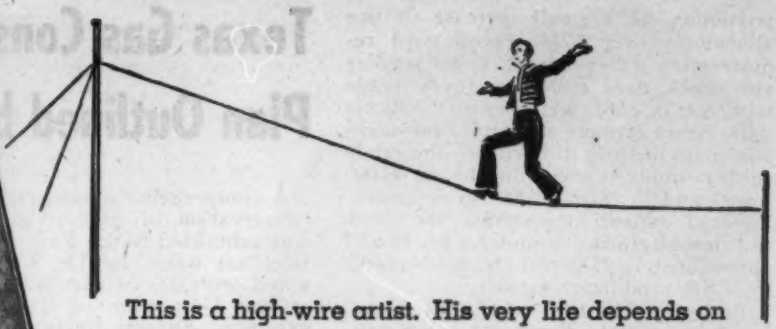

This is a high-wire artist. His very life depends on hair-trigger response to the slightest disturbance of balance. The same principle applies to any industrial process in which conditions of temperature, pressure or flow are subject to frequent variation. A process disturbance that isn't detected and corrected soon enough passes along to other parts of the process, finally upsetting product uniformity.

You know how the usual automatic controller works. A disturbance in the process causes a deflection of the recording pen.

This initiates a corrective action immediately.

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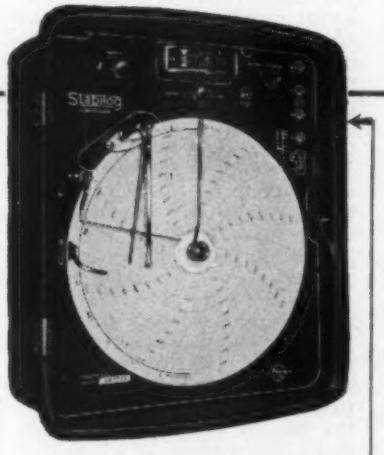
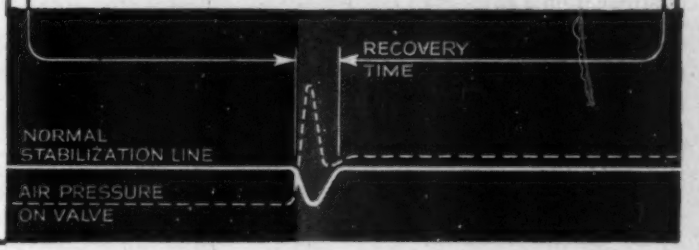


ONLY 1 ADJUSTMENT

Since HYPER-RESET combines both the rate-sensitive and the reset functions, one adjustment is sufficient to establish both settings.

In the Foxboro Stabilog Controller this recovery time is reduced by the automatic, super-alert HYPER-RESET function to a point never approached before. By sensing the rate of disturbance at its very start, HYPER-RESET also radically reduces the amount of upset. This curve shows how fast recovery takes place. Both actions are simultaneous. Rate-sensitive action and reset function are combined. And both are smoothly coordinated with the proportional function for normal process stabilization. *All this in ¼ the usual time and with the amount of upset held to a minimum!*



...and HYPER-RESET is only one precision feature of the Stabilog Controller

Obviously, the whole Stabilog Controller must be just as highly sensitive and readily responsive as any single part or function, such as HYPER-RESET. And those actions and functions must be perfectly coordinated in order to stabilize a process faster and wtih less upset. A good deal of this has been brought about by reducing friction, lost motion and inertia through the use of anti-friction bearings at critical points and by means of specially designed linkages. Stabilog Controllers reflect, in both design and operation, Foxboro's thirty years of process control engineering. Write today for your copy of Bulletin A330, describing HYPER-RESET Stabilog Control. **The Foxboro Co., 74 Neponset Avenue, Foxboro, Mass., U. S. A.**

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possibility of a small increase in tire allocations over 1944; rayon cord requirements will not be met and smaller size truck tires will have to be made with cotton cord, which in turn will vie with Army tentage demands; the manpower problem is still critical; the crude rubber supply is dwindling below 98,000 tons; and a $70,000,000 government-financed expansion program for truck tire manufacturing is under way, to add approximately 25 percent to the Nation's total tire production capacity.

Batteries: The 1945 supply of lead will be approximately 20 percent below estimated requirements; WPB will authorize construction of added facilities for battery production.

The gasoline allocation from PAW to ODT for the current quarter is 986,000 barrels daily, sufficient to meet ODT's estimated requirements except for a slight decrease in the East Coast and West Coast districts, short in the former by 9000 barrels and in the latter by 2000 barrels daily.

Foreign Economic Administration reports show gasoline exports from the United States—lend-lease and commercial sales, but excluding all military—amounting to 15,700,000 barrels in 1944.

"Increased gasoline supplies for use abroad are expected from the Near East and Middle East late this year," OWI said. "If the war's pace should slacken late in 1945 or if 'Victory-in-Europe' Day should arrive at that time, some surpluses may be available for civilian use, depending on a decrease, if any, in military demands. Officials cautioned, however, that more liberal rationing of gasoline after 'V-E' Day is contingent on a number of factors which would prevail at that time.

Bureau Shows 23 Million Barrels from Storage, 1944

Total demand for domestic crude oil in 1944 — 1,701,310,000 barrels — topped the production of 1,677,753,000 barrels by 23,557,000 barrels which had to be withdrawn from stocks, it was reported by the Bureau of Mines.

The bureau found that daily average demand during the year was 4,648,000 barrels, while production was 4,584,000 barrels and stock withdrawals 64,000 barrels. Total crude runs to stills amounted to 1,665,684,000 barrels, a daily average of 4,551,000 barrels.

Reporting on the current situation, the bureau said that preliminary figures show January demand was 4,720,000 barrels daily and indicate that demand in February may have run about the forecast 4,725,000 barrels daily.

For March a daily average demand of 4,742,000 barrels was forecast, comparing with PAW certifications calling for the production of 4,793,350 barrels daily.

Pressure Maintenance Plant Is Completed

A 60-million-cubic-foot capacity pressure maintenance plant, constructed for Trinity Gas Corporation in the Sejita field, Duval County, Texas, is now in operation. The plant is designed to produce approximately 1500 barrels of petroleum products daily, including aviation gasoline.

Gas from 15 wells in the Sejita field is processed at 1700 pounds per square inch and is then compressed to 2500 pounds and returned to the field sands.

The Sejita plant was designed by Hudson Engineering Corporation, Houston.

Texas Gas Conservation and Utilization Plan Outlined by Dr. E. P. Schoch

A comprehensive, long-range plan for conservation of natural gas in Texas was submitted to the Railroad Commission last week, by Dr. E. P. Schoch, noted professor of chemical engineering at the University of Texas. He has expressed himself freely on the whole subject of natural resource conservation many times, but not always has he gone into the solution of the problem he posed. This time, however, he was specific and to the point; not only did he state the problem and support it by a mass of evidence, but he suggested a solution and outlined the benefits that in his opinion would inevitably follow should the plan be put into effect.

The problem in gas today is similar to that of oil in 1931, Schoch declares. Then, due to the great surplus, crude oil sold for as little as ten cents per barrel in East Texas. The market demand proration law passed in 1932 steadied production and saved the day. Gas is being sold at the wells today at prices ranging from one cent to five cents per thousand cubic feet. "At this low price," he says, "it is being used for purposes for which lignite could be used and it is being exported in gradually greater amounts. Furthermore, large gas supplies which do not reach public pipe lines are used in a manner which secures a still smaller return than the gas reaching pipe lines. As a result of all this, the total amount of gas now withdrawn annually from the ground has increased to nearly two trillion cubic feet, and if this rate of increase is not checked, it may rise to three trillion in ten to fifteen years. Estimates of our known gas reserves range from 50 to 70 trillion cubic feet, and the probable discoverable amounts may double this; but this is strictly our maximum expectation. With an annual withdrawal of three trillion cubic feet, our gas age may be wholly at an end in 40 years, or possibly 30. It is the low price now paid for gas at the wells which is responsible for the present situation; and just as with oil, so in this case, proration based on the proper estimate of the *market demand* can cure the whole situation."

Schoch's Proposal

Summarized, the four-point proposal for conservation is as follows:

1. Gas to be used in large amounts (such as 100 million cubic feet, or more, per annum) for purposes for which lignite or other cheap solid fuels can be used shall hereafter be excluded by the Railroad Commission from their estimate of *market demand* for public gas lines; but this provision should not be used to decrease the total volume allowed for existing gas lines below the amounts they now carry.

2. The price to be paid to gas owners by pipe-line operators shall be gradually raised from its present figure to a figure near or above 10 cents, in accordance with the market demand as defined in the preceding paragraph.

3. To increase the market demand in Texas, there shall be instituted an effective program of industrialization aided by specific provisions for new industries, particularly those using clays, cotton, and natural gas itself as a material for manufacture.

4. Gas supplies such as those used for carbon black and for all lifting which are now disposed of through other means that "common carriers" should be given special technical study with the view of reducing unprofitable or wasteful outputs of gas.

These four actions can be expected to bring the following results, suggests Schoch:

Results of Program

a. The total income of gas owners will be increased from $23,000,000 to $100,000,000 per annum.

b. The length of the gas age will be made three to four times as long as it would be without such a procedure.

c. Pipe line investors will suffer no losses of income on their investment.

d. Texas prices of domestic and commercial gas will not be increased—perhaps even decreased; and special industrial gas will be available at lower rates than in the Northeastern states.

e. The higher fuel costs which large industrial users will have to bear will not affect them substantially because even with lignite, the fuel item is only one third of the total power cost. Furthermore, these large industrial users will be merely reassuming a cost which in the meanwhile is being carried mainly by the well owners, and in lesser degree, by the other fuel users.

In the opinion of Schoch, the Railroad Commission has the power and "duty to fix the prices which a pipe line should pay for gas offered to it by producers, and also the power and duty to pro-rate the amounts to be taken from the different producers." Thus the professor advocates a ratable taking law. If there is any doubt about the Railroad Commission's authority to act in this connection, then "legislative action to carry out this program should be taken promptly," Schoch urges.

The commission "also has the power and duty to fix the prices to be charged for gas delivered; hence if a 'cheap gas which now is replacing lignite' is no longer allowed as figuring in the *market demand*, then an increase in the volumes of gas used for the other uses will enable the Commission to raise the well-price and with it the price for industrial gas without disturbing the price of domestic or of commercial gas; and this procedure will gradually eliminate the use of gas which is replacing lignite," he contends.

The industrialized Northeastern part of the United States follows practices strictly in accordance with the proposed plan, it is said.

More extensive industrialization is the key to higher prices for gas at the well, Schoch says. Texas now has 776,000 domestic and commercial gas consumers which use 0.120 trillion cubic feet per annum, he points out. "Since," he explains, "the greater part of these are domestic consumers, averaging five persons per family, this indicates that about half of the people in Texas use gas in their homes, and a great increase in the consumption of domestic gas cannot be expected. Since the pipe lines now dis-

LIKE SNUFFING OUT A CANDLE

● Just a hint of a blaze in petroleum products—or other flammable liquids—and a Kidde built-in system goes into action fast. A blanket of carbon dioxide covers it like a candle-snuffer... out goes the flame before it can spread!

Fast fire-killing is just part of the Kidde method. The "after it's out" advantages are equally outstanding. Regardless of the severity of the blaze, the use of the dry, inert gas permits rapid access for repair of pipe lines without loss of cleanup time. Prompt extinguishing prevents further breaks in other pipe lines, restricting blaze to point of disturbance.

Remember, too, that Kidde equipment is approved by the underwriters for protection against electrical blazes (Class C) as well as against flammable liquid fires (Class B). Carbon dioxide penetrates wiring and windings to smother flames quickly—protects the equipment against water-soaking or rotting of insulation.

Are *you* fully protected against these two types of tough fires? Look over the list of hazardous areas—if even one of them is unprotected, call in a Kidde representative. He's ready to share his fire-prevention know-how with you.

Kidde Kills Tough Fires

- STORAGE ROOMS
- PUMP ROOMS
- TANK TRUCKS
- ELECTRICAL EQUIPMENT
- PAINT STORAGE
- ANTIFREEZE ROOMS
- PIPE LINE PUMPING STATIONS
- CASE AND CAN ROOMS
- CONTROL ROOMS
- LABORATORIES
- BULK PLANTS

K Kidde

THE WORD "KIDDE" AND THE KIDDE SEAL ARE TRADE-MARKS OF WALTER KIDDE & COMPANY, INC.

Walter Kidde & Company, Inc. • 140 Cedar Street • New York 6, N. Y.

Buell's assurance of...

HIGH EFFICIENCY LOW MAINTENANCE LONG LIFE

BELIEVING that progressive plant executives and engineers will welcome detailed information pointing up the reasons for industry's growing preference for Buell's advanced design in high-efficiency dust collecting systems, Buell will inaugurate a series of six explanatory advertisements descriptive of the engineering factors largely responsible for Buell's constantly increasing installations.

Look for these enlightening dust recovery messages in leading industrial and engineering publications. They will technically detail the advantages of the six outstanding Buell features briefed below.

1. *The "Shave-Off"*... The patented van Tongeren principle, exclusive with Buell. Utilizes the "double eddy" current, establishing a highly efficient collection force.

2. *Large Diameters*... Permit use of extra thick metal. Afford large dust outlets, prevent clogging. Reduce abrasion.

3. *Extra-Sturdy Construction*... Rolled and welded, one piece construction; hoppers braced with 3" channels to withstand vibration.

4. *Correct Hopper Design*... Plays a most important, often disregarded, part in dust collection efficiency. Dust disposal facility must be anticipated in the initial overall design.

5. *Split-Duct Manifolding*... A prime factor in efficient distribution of the dust load. Buell's manifolding method has flexibility, discharging gases from any side or end.

6. *Inner Welds Ground Smooth*... Proper finishing of inner welds effects operating efficiency, reduces erosion, ensures longer life.

buell
DUST RECOVERY SYSTEMS

The interesting Buell book—*"The van Tongeren System of Industrial Dust Recovery"*—has been especially prepared for operating executives and engineers.

BUELL ENGINEERING COMPANY, INC.
Suite 5000, 6 Cedar Street, New York 5, N. Y.
Sales Representatives in Principal Cities

DESIGNED TO DO A JOB, NOT JUST TO MEET A "SPEC"

tribute 0.556 trillion cubic feet annually in Texas, it follows that a large increase in commercial consumers is necessary in order to consume most of the present pipe line capacities and thus make it possible for the distributing companies to pay a higher well price.

"This increase in commercial users requires extensive industrialization: Not the bringing here of industrial giants, who by their size may be enabled to arrange for their own gas supplies direct from the wells, but the establishing of medium-sized industrial projects which will draw gas from public pipe lines, thus increasing the demand for commercial and special industrial gas.

"The efforts to industrialize Texas have been made for some years. In order to be effective, such efforts must be made by many; and fortunately, that is the case. However, there is an important part of our industrialization program which has been left out of consideration by others; namely, the setting up of industries with which our citizens are not familiar, or which are wholly new industries. Efforts to set up such new industries have been generally fruitless so far, because such ventures are unknown to investors, and difficult and costly. Hence, investors have to be given special help through Investors' Institutes. Such institutes, in order to be able to accomplish their tasks, must be specific for each industry, and of large scope."

In order to obtain additional "research and investor's institutes" of the same sort either now or in later years, Schoch recommends that the Legislature should go on record as favoring the granting of financial support for such projects, provided:

Three Institutes Suggested

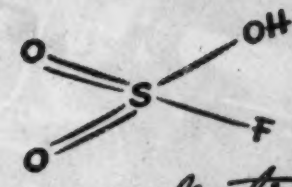
Each project is specific in the field it covers; each project is headed and directed by a competently trained man of the "Edison" type rather than an "executive"; and each project has been taken through an adequate initial developing stage with the expenditure of substantial funds to reveal the possibilities for which larger sums are asked.

To finance the three research institutes mentioned especially by Schoch, namely natural gas, clay products and cotton, he proposes that the Legislature give them about one fifth of the present tax receipts for gas, about $400,000 per annum, one half of which should go for development of new products from gas, inclusive of carbon, one fourth for the clay industry, and one fourth for new products from cotton. This assumes, he says, that the "University of Texas may start the program by furnishing the funds for the buildings and equipment necessary at an approximate cost of $400,000."

Among the products which new enterprises could produce in Texas, for which raw materials are already available, Schoch said, are: Agricultural and dairy products, processed foods ready for the consumer; forest products, particularly pressed boards, plywood, paper products from saw-dust waste; nonmetallic mineral products, particularly fine clay ware, art pottery, new wall tiles; tanning and leather products, ready for the trade; cotton and wool textiles and their products ready for the consumer; chemicals, raw plastics and crude rubber from petroleum and gas; manufactured articles from plastics and rubber.

Here's A NEW CHEMICAL TOOL BY GENERAL···

FLUOSULFONIC ACID



Potential Industrial Applications

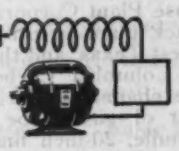
In preparation of Sulfamido Acids · Boron Trifluoride
Aromatic Sulfonyl Fluorides · Sulfuryl Fluoride · Alkyl
Fluosulfonates · Acyl Fluorides · Aryl Fluosulfonates
Other Alkyl Reactions.

Physical Properties

Mobile, nearly colorless liquid which fumes in damp air.
Boils at 330° F. (165.5°C.) under 760 mm Hg pressure.
Freezes at –125° F. (–87.3 C.)
Specific Gravity: 1.743 at 60° F. (15.6°C.)
Vapor pressure: 3 mm Hg at 80° F. (26.7° C.)
Specific Electrical Resistance: 205 ohms per cubic cm at 86° F. (30° C.)
Viscosity: 1.7 centipoises at 68° F. (20° C.)
Heat of Formation from SO_3 (l) and HF (g): 25 kilocalories per mole.
Most salts soluble in water.

FUTURE USES
of HSO_3F ($HO{\cdot}SO_2F$)

…lating agent in …facture of high …fuel for the post-"plane-mobile."



…ent in the pro… …ion of synthetic …ers with dielec… …roperties.

…nufacture of dye …mediates.

…producing high …ure lubricants, …g oils, etc.

…her research and …facture involving …nic or inorganic …icals.

General Chemical Fluosulfonic Acid may open up a new avenue of approach to many of your research problems. For data on physical and chemical properties, etc. *write for Technical Service Bulletin No. 33-A today.* Address your request to the Technical Service Office nearest you.

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…FIRST IN FLUORIDES

GENERAL CHEMICAL FLUORINE COMPOUNDS

Fluorides

Acid Hydrofluoric, Anhydrous
Acid Hydrofluoric, Aqueous
Aluminum Fluoride, Crystal
Ammonium Bifluoride
Ammonium Fluoride
Barium Fluoride
Boron Trifluoride
Chromium Fluoride
Cupric Fluoride
Fluoride Fluxes
Lead Fluoride
Lithium Fluoride
Magnesium Fluoride
Nickel Fluoride
Polyacid Fluorides (e.g. KF. x HF)
Potassium Fluoride, Anhydrous
Potassium Fluoride, Crystal
Sodium Bifluoride
Sodium Fluoride
Strontium Fluoride

Fluoborates

Acid Fluoboric
Ammonium Fluoborate
Cadmium Fluoborate
Chromium Fluoborate
Copper Fluoborate
Ferrous Fluoborate
Indium Fluoborate
Lead Fluoborate
Nickel Fluoborate
Potassium Fluoborate
Silver Fluoborate
Sodium Fluoborate
Stannous Fluoborate
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Fluosulfonates

Acid Fluosulfonic

GENERAL CHEMICAL COMPANY
40 Rector Street, New York 6, N. Y.

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In Wisconsin: General Chemical Wisconsin Corp., Milwaukee, Wis.

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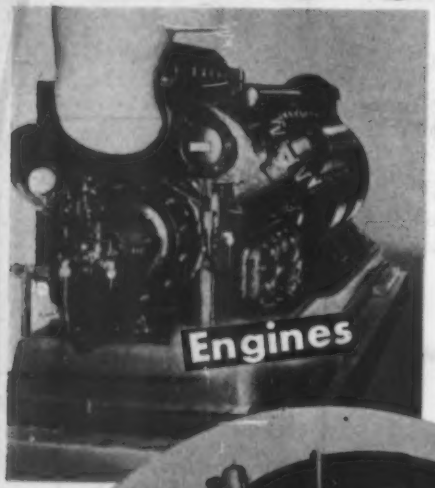
HAERING GLUCOSATES

for CORROSION and SCALE CONTROL



WRITE FOR "H-O-H WATER STUDIES"

WE READ WATER

D. W. HAERING & CO., Inc.
GENERAL OFFICES
205 West Wacker Drive, Chicago 6, Ill.

Army's Abandonment of Canol Project Pending

The Army is ready to close down the Canol project in Canada, part of which is the 3000-barrel refining plant at Whitehorse, and write off the investment as a strategic war expenditure. War department representatives were reported to have said present plans call for abandonment of operations after a resurvey of Canol's potentialities this spring, unless the combined chiefs of staff direct to the contrary. These disclosures followed a series of closed hearings by a Senate committee on investigation of war expenditures, at which War Department officials reported the operating results of the undertaking. Whether public hearings will be held has not been decided by the committee, but it was said a report is pending.

Improvement in conditions since the project was initiated makes possible the assignment of tankers to transport oil to Shagway, where it can be distributed by pipe line, more cheaply than it can be produced and refined in the Canol project, according to members of the committee. In other quarters it was said that if the department comes to Congress for more money to operate the project, it will be strongly opposed.

Evidence of the Army's intentions regarding the project is seen in the offer to sell, as surplus material, portions of a Houdry unit which had been planned for installation at Whitehorse. This equipment is at Los Angeles and will be sold by Defense Plant Corporation.

Second DPC West Texas Carbon Plant Started

Construction has been started in Defense Plant Corporation's second carbon black plant in the Seagraves sector of West Texas, and the plant will be leased to Columbia Carbon Company. Using the channel type, it will use 21,000,000 feet of gas to be supplied through a 14-mile, 20-inch line by Phillips Petroleum Company's Seminole natural gasoline plant.

Oil Supply and Handling Is Big Army Problem in Europe

Statement that two thirds of the tonnage shipped overseas to the Army is petroleum has been repeated to the extent that everyone is impressed with the volume required. However, the American Petroleum Institute's *Quarterly* for January gives these variations of the statistics, quoting figures then available:

The United States Army in France has received 7,443,692 barrels of gasoline and diesel oil in bulk landed on the shores of North France since D-day (June 6, 1944), and has stored, transported and packaged most of it. French get small quantities for civilian use. The imports of gasoline now average 79,570 barrels per day.

Ninety-seven percent of the gasoline and diesel oil landed in France is decanted into 5-gallon cans before going to the front. The United States Army has imported about 13 million cans for this purpose. At 4½ gallons each, these cans represent a possible floating storage of 58 million gallons, or almost 1½ million barrels. At one point in Northern France. 1¼ million gallons of gasoline were decanted from a pipe line into cans in a single day.

At the end of July, 1944, storage capacity was 297,000 barrels on the shores of North France, most of it built during the battle of the beaches. By the end of the year, storage was 1½ million barrels. Al-

an Old Product

TAKES ON NEW TASKS

Plain, old-fashioned Bicarbonate of Soda is an amazingly versatile chemical product. Household remedy for many common ills . . . key ingredient for dozens of pharmaceuticals . . . basic in baking powder and millers' choice for self-rising flour—"bi-carb" plays its homely, useful roles.

"Bi-carb" is just as essential in hundreds of industrial operations . . . is the active ingredient in several types of fire fighting equipment . . . helps tan leather . . . prevents sap stain in lumber . . . performs importantly in the production of plastics, sponge rubber and in heat-treatment of special steels . . . neutralizes acids and removes caustic.

Through Mathieson Research, "bi-carb" assumes great new importance in the textile industry. Commercially developed, Mathieson's new process for removing caustic with "bi-carb" speeds up production, lowers cost, eliminates acid's disadvantages . . . removes caustic by *changing* it into sodium carbonate (soda ash).

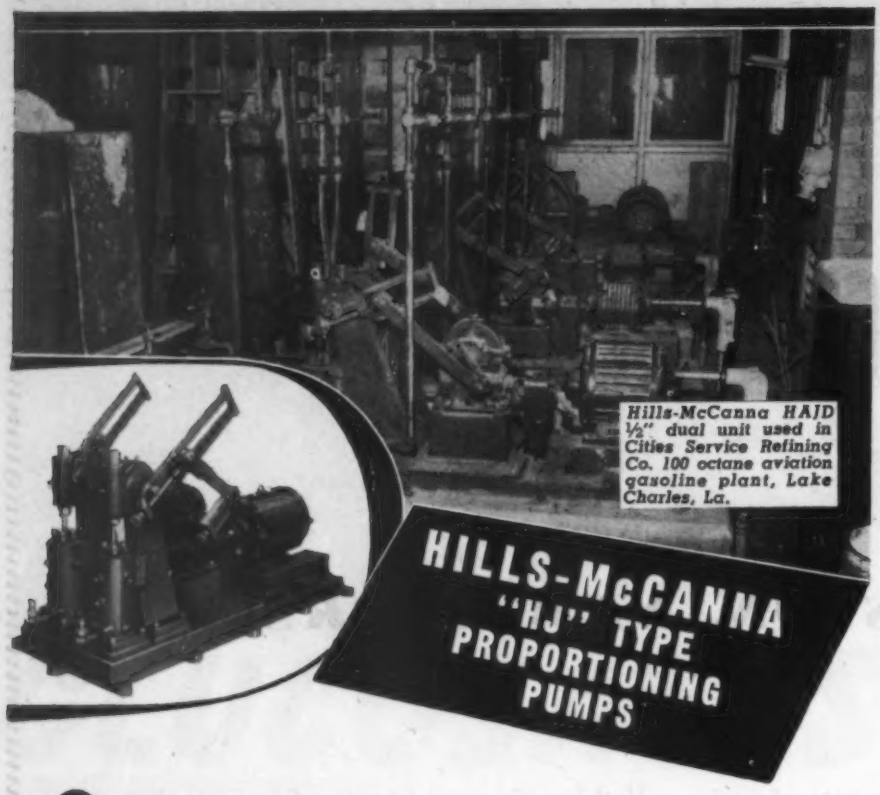
The Mathieson Research and Technical Staffs are also applying "bi-carb" experience to certain phases of the paper industry. Perhaps their accumulated knowledge of "bi-carb's" versatility may hold important meaning for you—may bring to light possibilities you haven't thought of. *Co-operation means progress for all.*

Mathieson
CHEMICALS

THE MATHIESON ALKALI WORKS (INC.) 60 EAST 42nd ST., NEW YORK 17, N. Y.

BICARBONATE OF SODA . . . CAUSTIC SODA . . . SODA ASH . . . LIQUID CHLORINE . . . CHLORINE DIOXIDE
AMMONIA, ANHYDROUS & AQUA . . . . H T H PRODUCTS . . . . FUSED ALKALI PRODUCTS . . . . SYNTHETIC SALT
CAKE . . . . DRY ICE . . . . CARBONIC GAS . . . . SODIUM CHLORITE PRODUCTS . . . . SODIUM METHYLATE

For Pumping Liquids that must be chilled or heated


Hills-McCanna HAJD ½" dual unit used in Cities Service Refining Co. 100 octane aviation gasoline plant, Lake Charles, La.
HILLS-McCANNA "HJ" TYPE PROPORTIONING PUMPS

This Hills-McCanna unit is especially designed for use where liquids or gases must be heated or chilled to keep them in a liquid pumping state. Propane and Butane, for example, can be kept in liquid form by circulating a cooling medium through the jacketed section. Paraffin, phenol, tar and other products are handled by circulating steam through the jacket.

The Hills-McCanna HJ Pump features a heavy duty driving mechanism to supply adequate pressure. Adjustment for variation of volume is standard and a special adjustment is available for varying volume while pump is in operation. Capacities range from 126.0 G.P.H., pressures to 5,500 P.S.I.

Write to "Proportioning Pump Headquarters" for data on other Hills-McCanna Pumps, available for capacities to 1,500 G.P.H., pressures to 22,500 P.S.I. HILLS-McCANNA COMPANY, Chicago, Illinois.

Ask for your copy of CATALOG P-44
(shown at left)
Hills-McCanna Lubricators (enclosed Type "VSF" illustrated) to serve every need. Available with 1 to 32 pint reservoirs, 1 to 48 feeds.

HILLS-McCANNA COMPANY

2441 W. Nelson St., Chicago 18, Ill.

Proportioning Pumps — Force-Feed Lubricators — Chemical Valves
Air & Water Valves — Marine Valves — Magnesium Castings

most a million barrels of this was built in the last two months of the year. Construction continues steadily.

Up to November, 1944, the Army Air Forces had used more than 2 billion ballons of 100-octane gasoline and expended only 238 million rounds of ammunition. United States military demands for gasoline reached 800,000 barrels daily in 1944, a jump of 433 percent since Pearl Harbor. Fourteen million barrels of gasoline and oil are going overseas to fighting forces each month.

Fifteen percent of the United States crude oil production was converted into aviation gasoline during January, 1945. Before Pearl Harbor it was ½ of 1 percent, or 40,000 barrels per day.

In 1944, 50 million gallons of engine oil, 3 million gallons of gear lubricants, and 45 million pounds of grease were shipped overseas.

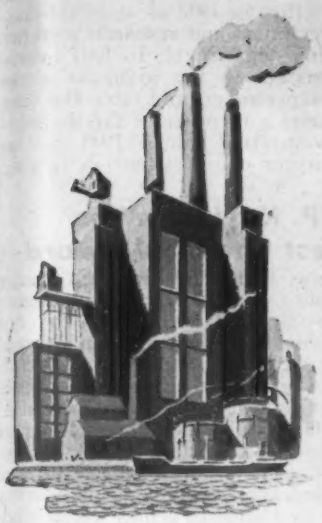
Ferguson Made Humble Director of Refining

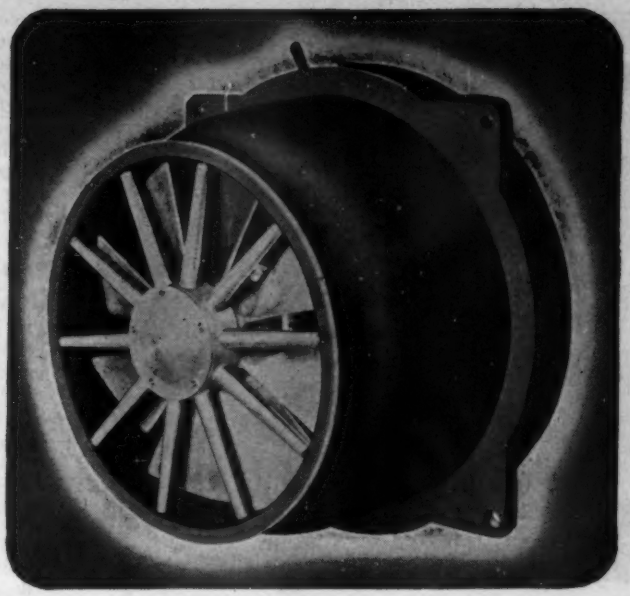
Humble Oil & Refining Company stockholders meeting at Houston February 12 reelected directors with the addition of Harry W. Ferguson, and created the office of executive vice president. Directors subsequently elevated Hines H. Baker to the executive vice-president post, and designated Ferguson director of refining. L. T. Barrow, a director, was named vice president in charge of production, to replace John R. Suman, who has been elevated to vice president and director of Standard Oil Company (New Jersey) and moved to New York.

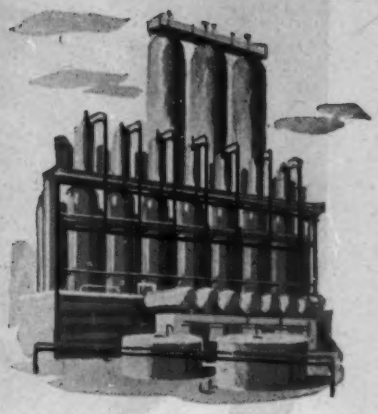
Baker has been a member of the board of directors since 1937, and for the past four years has been vice president in charge of refining and sales. He joined the company's legal department in 1919.

Ferguson joined the company as a chemical engineer in the development department at Baytown refinery within a few weeks after receiving his degree in chemical engineering at University of Michigan in 1924. After serving as chief of both the cracking and technical

Harry W. Ferguson

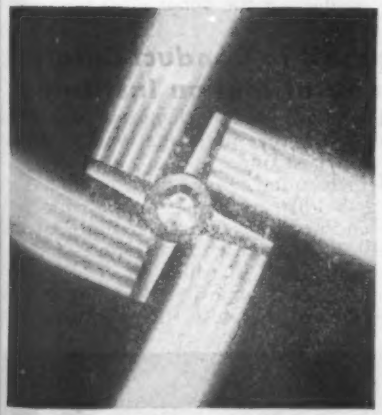






"PINWHEEL ACTION" BURNER

INCREASES BOILER RATINGS



Coppus-Dennis FANMIX Uses New Principle to Create "Flameless Fire" and Get More Heat from Gas or Oil

Greater heat release results from the unique Dennis principle of combining fuel with air in a perfect mixture to provide truly radiant heat — "flameless fire".

On natural gas, for example, FANMIX provides complete combustion with less than 5% excess air in the product of combustion leaving the furnace.

Increase ratings of equipment now operating at limit of present burners. Install FANMIX . . . easily, economically . . . and get more heat.

Coppus engineers FANMIX Burners for individual applications. Complete control over rate of combustion or "flame pattern" can be provided to meet the requirements of any installation. Coppus Engineering Corporation, 103 Park Ave., Worcester 2, Mass. Sales offices in THOMAS' REGISTER. Other Coppus "Blue Ribbon" products in SWEET'S, CHEMICAL ENGINEERING CATALOG, REFINERY CATALOG.

"Pinwheel Action" Gives Perfect Proportioning

Fuel escaping from orifices in rotating driver arms, rotates the fan, which draws in air at right angles to the path of the fuel. The energy in the fuel under pressure is utilized to perform work by mechanically mixing and proportioning the fuel automatically with just the required amount of air.

This homogeneous mixing secures complete combustion. Uniform temperature conditions exist throughout the furnace, with complete absence of drifting "hot spots".

New Installations — FANMIX Cuts Investment Cost

Smaller combustion space — furnace is relieved of having to serve as mixing chamber. Less stack — FANMIX creates its own forced draft, overcoming draft loss across the burner. No forced draft equipment — FANMIX draws air for combustion through air-cooled walls or floors.

2 Types — Straight Gas or Combination Gas-Oil

Combination burners burn either oil or gas in entirety or in any proportion. No oil guns needed.

ANOTHER
COPPUS
"BLUE RIBBON" PRODUCT

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283 Park Ave.,
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New Bulletin Will Tell You How to Increase Thru-Put of Your Gas- or Gas-Oil Fired Equipment.

Please send me Bulletin 410-4

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Company.....

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- Exceptional anti-friction properties . . . becomes a smooth, bearing-like sleeve in service.
- Completely malleable—may be hammered or rolled to fit any size stuffing box.
- Longest-fibre asbestos for extra strength and longer life.
- Wide usefulness . . . a general purpose packing for industrial, mining, railroad, marine services.

This Palmetto Packing has ultra-high resistance to friction and heat. It does not dry out or harden—no liquid lubricant to be squeezed out or melted.

Derives its lubricating properties from *graphite* and soft flakes of anti-friction *bearing metal,* which form a wearing surface of low friction.

Wherever Plastic Metallic Packings are to be used, you can be SURE of best results with PALMETTO . . . available NOW for prompt shipment.

USED FOR
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Valves of All Types
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PACKS
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PROMPT DELIVERIES

Coil Form Now Ready

Supplied in square shape, coil form. Order from your local Greene, Tweed distributor, or, if necessary, direct from us.

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Plants at New York, N. Y., and North Wales, Pennsylvania

PALMETTO *Self-Lubricating* **PACKINGS**

for steam, water, air. PELRO for oils. CUTNO for alkalis. SUPERCUTNO (blue asbestos) for acids. KLERO for foods.

service divisions of the development department at Baytown, he moved to the Houston office in 1933 as assistant manager of technical and research work for the refining department. In 1937 he was made assistant to the manager of the refining department, and later the same year became a member of the manufacturing committee. Since 1941 he has been manager of operations in refining.

Lucas P. Kyrides Wins Midwest Chemical Award

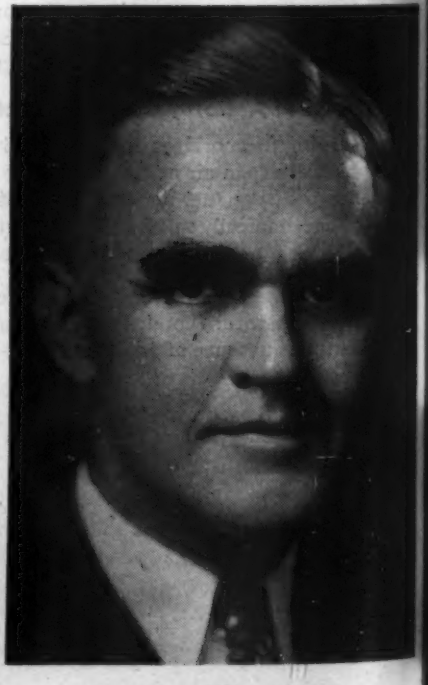
Dr. Lucas P. Kyrides, research director of Monsanto Chemical Company's organic chemicals division, was given the first Midwest Award of the American Chemical Society's St. Louis Section on March 5. Dr. Kyrides was the principal speaker at the dinner at which the award was made, outlining advances which have taken place within the span of his own career in chemistry. Not widely known outside his own field of endeavor, he is recognized among scientists as a creative genius whose handiwork has touched many shades of American life. He pioneered development of synthetic rubber in this country, and has made important contributions in chemicals important to the nation's economy.

The award, a gold medallion, is to be given each year to the individual adjudged most outstanding in the point of "meritorious contribution to the advancement of pure or applied chemistry or chemical education." Chemists residing in Missouri, Kansas, Iowa, Oklahoma, Nebraska, Arkansas, Kentucky, Tennessee and Illinois are eligible for the honor.

Emmett to Conduct Catalyst Study at Mellon Institute

Dr. Paul Hugh Emmett has been added to the investigational staff of Mellon Institute.

Dr. Emmett, born in Portland, Oregon, in 1900, received his B.S. in chemical engineering at Oregon State College in 1922. His graduate work was pursued at California Institute of Technology, where he was awarded Ph.D. in 1925. In 1939 Oregon State College conferred on



DR. PAUL HUGH EMMETT

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Designed and built to give a good account of themselves under the most severe conditions. "From Foundry to the completed Valve" is the SOLECO story. Write for our latest booklet!

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MANUFACTURERS OF INDUSTRIAL AND PETROLEUM STEEL PRODUCTS

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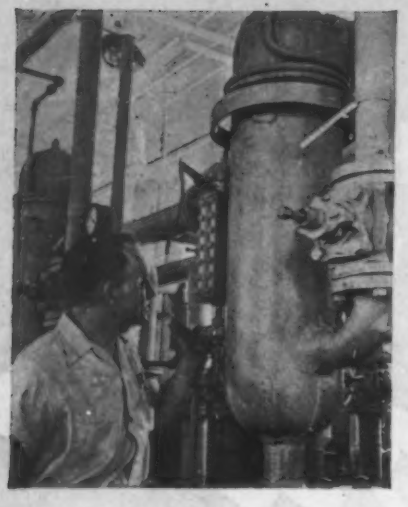

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GAGES
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REFINERY
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TRULY the JERGUSON Gage has universal application.

Here you have two widely different applications although both are "petroleum." Both are "Reflex Gages" the type that provides maximum readability. One is out in the field where production is carried on; the other is in a butadiene plant.

The Line of JERGUSON Gages is extensive. In both Reflex and Transparent Types, there is the range necessary to take care of the petroleum industry's gage requirements. Standard Reflex Gages are designed for pressures up to 3200 pounds at 100° F. or 1200 pounds at 1200° F. Transparent Gages are designed for pressures up to 2000 pounds at 100° F. or 600 pounds at 1000° F.

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87 FELLSWAY SOMERVILLE 45, MASS.
3-JV-2

him an honorary Sc.D. He was engaged in studies on catalysis at the Fixed Nitrogen Laboratory of the United States Department of Agriculture, Washington, from 1926 to 1937, with the final rank of senior chemist, and during that period served as lecturer on catalysis at George Washington University. From 1937 until his appointment at Mellon Institute he was professor of chemical and gas engineering at Johns Hopkins University and also consultant of the United States Department of Agriculture. Recently he has been productively active in wartime essential research for the government, on leave of absence from Johns Hopkins.

Dr. Emmett has made many contributions to the literature of adsorption and nitrogen fixation as well as catalysis. He is also an associate editor of the Journal of the American Chemical Society. At Mellon Institute he will plan and supervise long-range investigational projects on catalysis of importance in petroleum technology, having the grade of senior fellow, in which positional capacity he will be aided by a group of capable scientists.

Professional Employes at Whiting Elect Officers

T. F. Doll has been elected president of the Research and Engineering Professional Employes Association of Whiting, Indiana. J. A. Anderson, vice president, H. R. Stover, secretary, and H. R. Taliaferro, treasurer. Officers are elected semi-annually by a seven-member board of directors elected by the membership. The association is the collective bargaining agency for the professional research and engineering personnel at the Whiting refinery of Standard Oil Company (Indiana). Formerly represented by a union including all refinery employes, numbering about 5000, the professional research and engineering employes felt their interests were not being adequately represented by the general union, and organized their own association in July, 1943. It since has been recognized officially by the government bureau.

Whiting refinery employs 200 technical workers, and 90 percent of these are members of the association. Since organization, 14 members have been lost because of advancement to managerial positions.

The association was formed, it was said, to reserve a trend in which the professional workers considered their interests were suffering from neglect, and less than a fifth of their number belonged to the plant union in which they represented a very small minority.

Proudfit, Prioleau Advance In Creole Organization

Arthur T. Proudfit has been elected president of Creole Petroleum Corporation and Horry F. Prioleau has been elected executive vice president. Proudfit formerly was vice president and general manager of all operations in Venezuela. He succeeds C. H. Lieb, who died December 30, 1944.

Prioleau, whose experience has been largely in foreign refining operations, has been a vice president and director. He will as executive vice president become the company's chief executive official in New York.

He was born in Charleston, South Carolina, where he began work in the refining plant of Standard Oil Company of New Jersey following graduation

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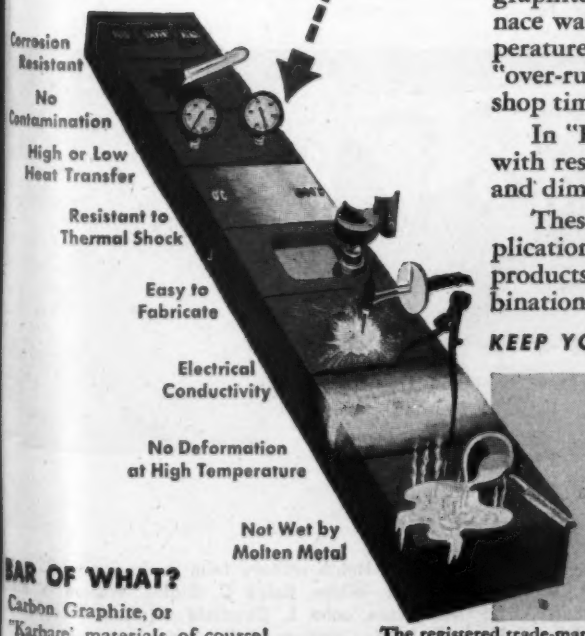
CARBON has *low* heat transfer properties. Graphite has *high*. Paradoxically . . . because they are one and the same element! We manufacture both forms . . . as well as "Karbate" material which is either one made impervious to fluid seepage.

The paradox makes possible widely diversified uses of carbon and graphite. Built-up carbon furnace linings, for example, *insulate* outer furnace walls, while keeping their strength and shape at the highest temperatures encountered. In contrast, graphite chill molds for furnace "over-runs" *cool metals quickly* without cracking or sticking, and save shop time, materials and mess.

In "Karbate" heat exchangers, high heat transfer goes hand-in-hand with resistance to practically all corrosive chemicals . . . plus strength and dimensional stability.

These and many other chemical, metallurgical or textile industry applications of "National" carbon and graphite and "Karbate" specialty products depend on their sometimes paradoxical but always broad combination of useful properties. Inquiries are invited.

KEEP YOUR EYE ON THE INFANTRY . . . THE DOUGHBOY DOES IT!



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Layne installed wells and Layne vertical turbine pumps are fully recognized by the most eminent engineers as being the finest in quality and the most efficient ever built.

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VERTICAL TURBINE PUMPS

from the University of Virginia in 1921. In 1925 he went to New York as assistant to the general manager and his work came to include activities in Latin America and other foreign countries.

In 1929 he went to The Hague as head of the refining department of N. V. Nederlandsche Koloniale Petroleum Mij., an affiliate of Standard Oil Company (New Jersey). Five years later he became general manager at The Hague where he remained until forced out by the German occupation of Holland in 1940.

Upon returning to New York he worked for various foreign operating units of Standard Oil Company (New Jersey). He became assistant to the president of Creole Petroleum Corporation in 1943 and a vice president and director in 1944.

Creole Petroleum Corporation has two refining plants in Venezuela.

HORRY F. PRIOLEAU

Heath Anniversary Dinner Honors Its Old Timers

The Pure Oil Company's Heath refinery, near Newark, Ohio, celebrated its twenty-fifth anniversary on March 1 with a dinner at which 400 refinery employes and their wives heard praise for their contribution to the war effort. Commander Roy H. Callahan, veteran naval aviator recently returned from Pacific service, was the speaker at the dinner. J. Porter Langfitt, assistant to the vice president in charge of refining, presented a 25-year service pin to E. E. McPherson, Heath superintendent, who started work in the plant 10 days before its operations started in 1920. McPherson has been superintendent since 1930, and the four others who held that position at Heath refinery are still with the company. Other speakers were R. D. McClaran, Heath superintendent, 1927-30, marketing director at Indianapolis; G. Ray Fenner, marketing director at Columbus, Ohio, and Daniel E. Sullivan, refinery chief engineer, Chicago, who set stakes for the original plant. John Stadtherr, refinery chemist, presided.

Other guests included Russel L. Vernor, Heath's superintendent from 1920 to 1933, now manager of marine operations at Beaumont, Texas; Clyde L. Smith of Chicago, refinery chief engineer, and Irwin L. Hostetler, former assistant superintendent at Heath and now assistant superintendent at Nederland, Texas.

Highlights of the chronology of Heath refinery as reviewed in a brochure issued for the occasion: Construction was started in May, 1919, with C. B. Watson, now vice president of the company, among those in charge. Original plant processed 2000 barrels per day. In 1922, four small Cross cracking units were built, the company being among the earliest to install such equipment, and Dr. Walter M. Cross, inventor of the process, was a constant visitor when these stills were being built. In 1926, two large Cross units, still in operation, were installed. In 1928, two small gyro units were built, followed by two larger units of that type in 1930. These units were dicarded in 1937, when in acompany-wide modernization program, a combination selective-cracking unit was built. in 1943 a catalytic polymerization unit was installed to complete the plant as it now stands with a capacity of 18,000 barrels daily.

These men have been with The Pure Oil Company's Heath refinery from its beginning 25 years ago. Left to right: Charles R. Walters, Carroll E. White, Ralph C. Brown, Warren A. Rice, Charles G. Swart, J. Burl Fluharty, E. E. McPherson, John E. Oberfield, William F. Nikolaus, Ray T. Schuler and Otto E. Adams. Elmer E. White, another of the group, was not present.

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Surface Executive Assistant To New Jersey President

Dr. Frank M. Surface has been appointed executive assistant to Eugene Holman, president of Standard Oil Company (New Jersey). Surface has been coordinator of sales research for the company since 1943, prior to which he was for 10 years director of sales research for Standard Oil Company of New Jersey. An authority on economics and author of many articles and books on the subject, he formerly was assistant director of the Bureau of Foreign and Domestic Commerce. After attending Ohio State University and receiving his doctorate at University of Pennsylvania, he spent several years in biological research at various universities, and became assistant chief of the statistical division of the U. S. Food Administration during World War I. He served as food statistician with the American Peace Commission in Paris after the war, and as chief statistician for the American Relief Administration in Europe. He returned to Washington in 1921 as special agent for the Bureau of Census, founded and edited "Survey of Current Business" for the department, and became assistant director of the Bureau of Foreign and Domestic Commerce in 1927. He was visiting professor of marketing at Stanford University Graduate School of Business in 1929-30.

Argyle Advanced, Barnes Added to PAW Staff

William R. Argyle, who has been assistant director of the refining division of the Petroleum Administration for War since September, 1943, has been named associate director of the division. Bonner Barnes, general superintendent of Gulf Oil Corporation refineries in Texas, has been appointed assistant director of refining in charge of refining operations and technical processes, to succeed Argyle.

Before joining PAW, Argyle was assistant manager of refineries for Sinclair Refining Company, having been

WILLIAM ARGYLE

BONNER BARNES

with the organization since 1920. He is a graduate of the University of Utah, and served two years as a physicist with the Bureau of Mines.

Barnes has been with Gulf Oil Corporation since shortly after graduation as a chemical engineer from Texas A. & M. College in 1921. From June, 1929, to March, 1935, he was superintendent at Sweetwater, Texas, and Toledo, Ohio. He became assistant general superintendent of the company's plants in Texas in 1935, and in 1939 was promoted to general superintendent of refineries in Texas, with offices at Port Arthur.

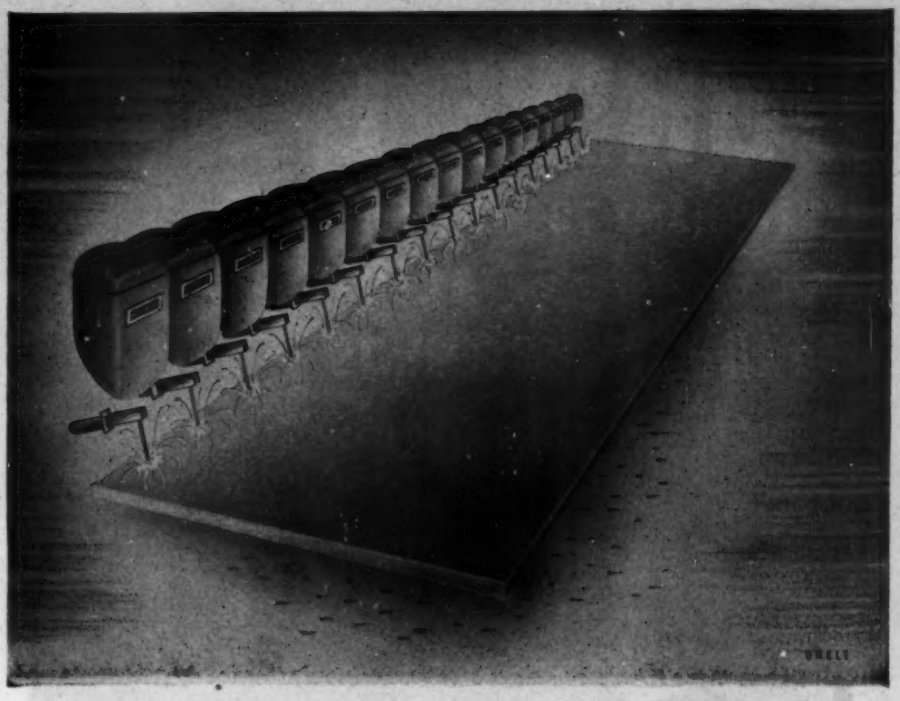
Faulkner Heads Gulf Refineries in Texas

R. C. Faulkner was named general superintendent of Gulf Oil Corporation's refining plants in Texas, to succeed Bonner Barnes who is in Washington as assistant director of refining for Petroleum Administration for War. Faulkner's assistant general superintendents include G. I. Roberts, T. F. Hogan and L. O. Crockett, all with headquarters at Port Arthur.

Superintendent for Gulf Retires After 43 Years

Herman Taylor, superintendent of Gulf Oil Corporation's refinery at Fort Worth, Texas, retired January 31. He is 70 years old, and had been with the company since 1902 when he joined a predecessor, Guffey Petroleum Company, at Port Arthur. Thirty-three of his 43 years of service was at Fort Worth where he went in 1912 as assistant superintendent, and was made superintendent in 1918.

Another veteran, John W. Schriever, has been moved from Sweetwater, Texas, to succeed Taylor at Fort Worth. Shriever joined the company at Port Arthur 30 years ago, and after serving as assistant superintendent at Cincinnati, became superintendent at Sweetwater in 1936. A. L. Giesen has been transferred from Port Arthur to be superintendent at Sweetwater.



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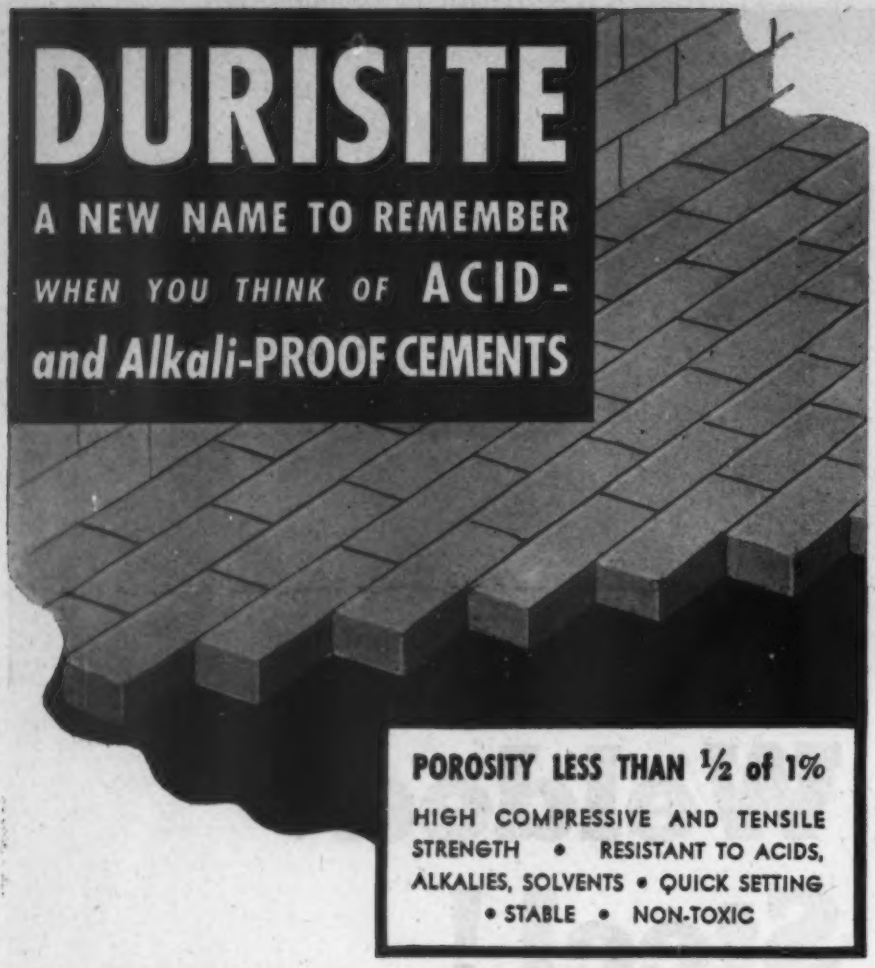

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Thiede Named Manager of Standard New Jersey Works

William F. Thiede has been appointed manager of the New Jersey Works of Standard Oil Company of New Jersey, including refineries at Bayway and Bayonne, and Eagle Works in Jersey City. He succeeds the late G. H. Mettam.

Thiede has been with the company nearly 33 years, starting in 1909 as an errand boy during school vacations, and becoming a regular employe in 1912. Following several years in the oil-movement and storage department he was placed in charge of that department. He was made assistant superintendent in 1926 at Bayway, in charge of atmospheric distillation and oil movement and storage. Appointed assistant general superintendent in 1936, he was transferred two years later to Bayonne refinery as acting general superintendent, later becoming general superintendent. He was made assistant manager of New Jersey Works in 1944.

Sanders Superintendent of Ohio Standard Lube Plant

Dr. F. J. Sanders, formerly superintendent of The Standard Oil Company's (Ohio) refinery at Toledo, has been placed in charge of the company's No. 2 Refinery at Cleveland. The latter plant is devoted exclusively to manufacture of lubricating oils, greases and waxes.

Dr. Sanders graduated in chemical engineering from Texas Technological Institute, and secured his doctorate in chemical engineering at Yale in 1933. After a brief period in the dye industry, he joined The Standard Oil Company in 1934 to organize the technical service group of the process department's process and development division. He was placed in charge at Toledo in 1939. While there, a number of new units were installed, including alkylation, catalytic polymerization, cumene and dimer units. His new assignment, it was said, is to make his refining and technical experience available for development and manufacture of new lubricants.

Bureau Shifts Top Men At Bartlesville Station

N. A. C. Smith, supervising engineer of the Bureau of Mines petroleum experiment station at Bartlesville, Oklahoma, has been reassigned as special assistant to the supervising engineer. H. C. Fowler, assistant chief of the bureau's petroleum and natural-gas division, has been traneferred from Washington to succeed Smith at Bartlesville.

Dr. R. R. Sayers, director of the bureau, said in announcing the change that it was at the request of Smith who wished to be relieved of administrative duties because of his health. As special assistant, Smith is to handle specialized research and technical writing. His connection with the bureau dates back to 1918, six years after graduation from Clark University. He worked in various phases of petroleum chemistry at Washington and Pittsburgh until transfer to Bartlesville in 1923 to be in charge of the station's work on petroleum chemistry and refining. In 1926 he was appointed superintendent, the title later being changed to supervising engineer. Development of the station to its important place in petroleum research has been under his supervision, and praise

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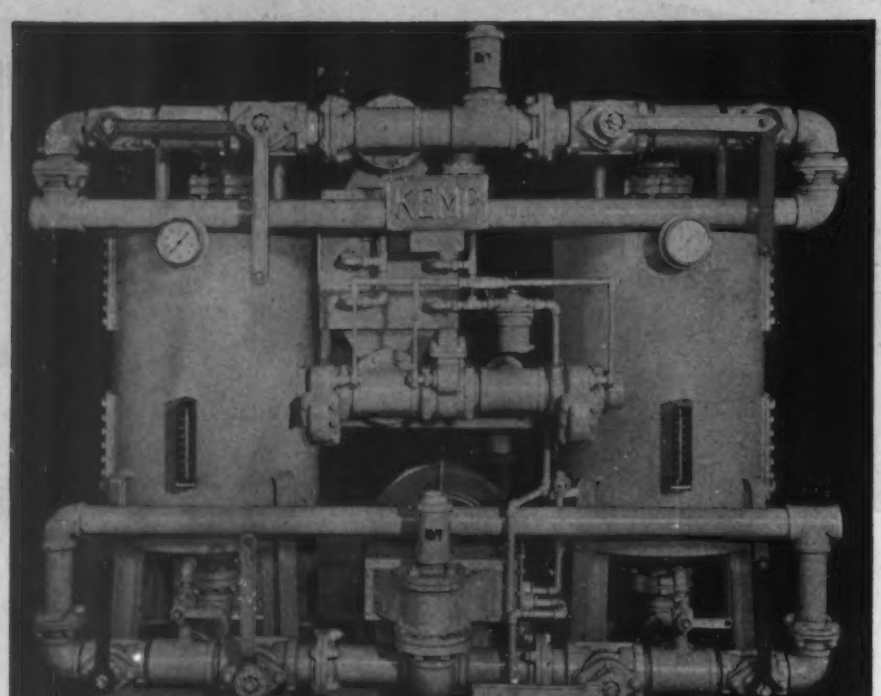

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KEMP of BALTIMORE

for this was included in the official announcement of the change. During his early years with the bureau Smith contributed a number of important publications to the literature.

Fowler graduated from Stanford University and was employed by California oil companies for several years before joining the bureau in 1923. After working at Bartlesville until 1927 he was transferred to Washington, where his work has kept him in close touch with developments at field stations. He is author of a number of bureau publications on oil and gas technology.

Fisher and Katz Join Gas Institute Staff

Morris Fisher and Dr. Sidney Katz have been added to the technical staff of the Institute of Gas Technology, 3325 South Dearborn Street, Chicago.

Fisher, a specialist in micrometrics, has been assigned to work on an improved method of producing carbon black. He was a chemist for eight years with the Bureau of Mines at Pittsburgh, and during the last year has done research on a special project at Columbia University. He holds the bachelor and master of science degrees from Carnegie Institute of Technology, where he also taught chemistry.

Dr. Katz will work in the field of gas chemistry, particularly in the physical chemistry of fundamental gasification reactions. His first assignment is a special project for the National Research Council. Formerly research chemist for Goldsmith Brothers, Chicago, and for Pfaustiehl Chemical Company, Waukegan, Dr. Katz has served for two years as lecturer in mathematics at Illinois Institute of Technology. He received his Ph. D. at McGill University, Montreal, after earning his bachelor's and master's degrees at the University of Manitoba. In 1937 he was awarded a traveling fellowship in chemistry by the Royal Society of Canada.

Benjamin Miller has resigned as technical assistant to the director of the Institute of Gas Technology, effective April 30, to engage in consulting practice in New York. He will continue to serve the institute as a consultant

Mid-Continent Makes Tulsa Refinery Promotions

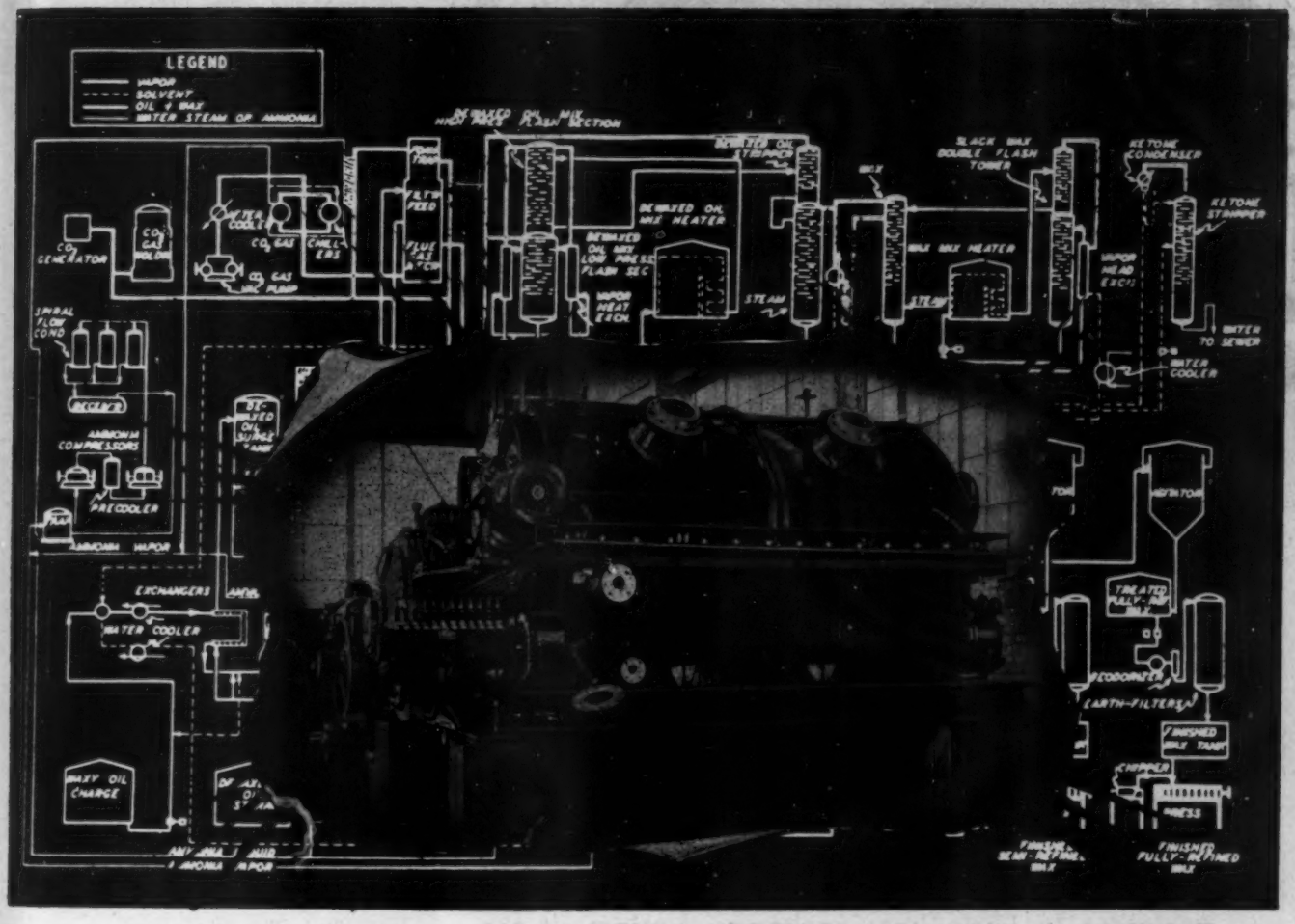
Mid-Continent Petroleum Corporation announced the following promotions at its Tulsa refinery: D. Glenn Morgan, from manager to general manager; Glenn E. Wynn from superintendent to general superintendent; Edward M. Dons, from assistant general superintendent to first assistant general superintendent; Fred B. York, from superintendent of the lube processing department to second assistant general superintendent; Harry Morton, from superintendent of stills and fire chief to superintendent of distillation.

Breth and Schindler Made Sonneborn Vice Presidents

Dr. F. W. Breth and Gustave Schindler have been elected vice presidents of L. Sonneborn Sons, Inc., New York.

Dr. Breth, who will serve as vice president in charge of manufacturing, joined the company in 1915 as chief chemist, and later was named technical director. His work has included extensive research on crystallization of paraffin waxes and development of a process

FILTERS



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for their manufacture. He is author of a number of papers on petroleum research projects, and has been active with technical committees of several national associations.

Schindler has been associated with refineries producing specialized products since starting his business career in 1928, and since 1939 has served as president of Petroleum Specialties, Inc., in New York, a connection which he will continue. His knowledge of and contact with foreign markets is expected to be an important factor in development of Sonneborn's export operations.

Everett Refinery Worked 2,880,716 Hours Unhurt

Everett Refinery of Colonial Beacon Oil Company, Everett, Massachusetts, continued its no-accident record (PETROLEUM REFINER, *July, 1944)* 1008 days, for a total of 2,880,716 man-hours. Beginning in December, 1941, the period of no accidents ended in September, 1944, when an experienced man crushed his finger while replacing a manhole cover. Pride of the workers was such that the injured man was said to have regretted marring the record more than loss of the finger.

For its accomplishment, the refinery was given the Liberty Mutual Insurance Company Safety Award, with speech-making and other ceremonies early in February.

Everett Refinery's system of safety has been in effect since 1930, when the first full-time safety engineer was employed and the first workmen's safety committee established. There are nine committeemen, representing all parts of the operations, and each now serves six months. New committeemen are given special training in first aid; in the need for protective clothing, shoes, goggles and other equipment; in artificial respiration, and in the location of safety equipment around the yard. They are in daily contact with the plant safety engineer and meet twice a month to discuss problems. At the end of each term the retiring committee attends a joint dinner with the new committee, as guests of the company.

W. Alton Jones Heads API Aviation Committee

Appointment of a committee on aviation, with W. Alton Jones, president of Cities Service Company, as chairman, and Bert I. Graves, vice president of Tide Water Associated Oil Company, as vice chairman, has been announced by the American Petroleum Institute.

The committee will function in an advisory capacity on over-all policies and procedures on petroleum matters related to aviation.

"Postwar aviation development, and legislation affecting it, will be of tremendous interest to the petroleum industry," William R. Boyd, Jr., president of the institute, said in advising members of the committee of their appointment. "Safety, traffic control, taxation, aviation fuels and lubricants and likely numerous problems of engineering and technology are among the things that naturally suggest themselves as being of interest and concern. The future of aviation and its relationship to the petroleum industry are very live subjects and it is to advise with respect to general policies of appropriate interest and proper con-

End view of reactor under construction showing nickel lining. Nickel butt straps were applied over all welds.

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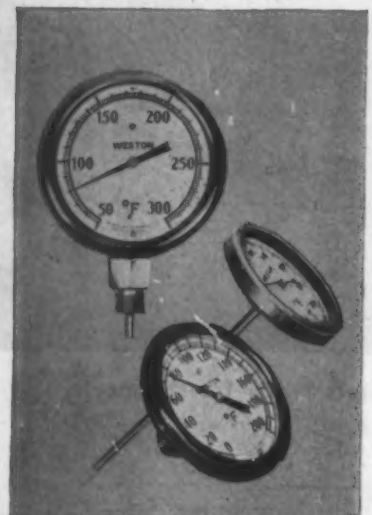

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WESTON

cern that this standing committee is created."

Members of the committee are: Hines H. Baker, Humble Oil & Refining Company; Thomas H. Barton, Lion Oil Refining Company; R. F. Bradley, Standard Oil Company of California; Paul G. Blazer, Ashland Oil & Refining Company; H. E. Brandli, Cities Service Oil Company; C. C. Carpenter, Union Oil Company of California; J. W. Connelly, Standard Oil Company (New Jersey); H. W. Dodge, The Texas Company; James E. Dyer, Sinclair Refining Company; Sylvester Dayson, Premier Refining Company; Walter L. Faust, Socony-Vacuum Oil Company; D. P. Hamilton, Root Petroleum Company; W. V. Hartmann, Gulf Oil Corporation; Charles F. Hatmaker, Pan American Petroleum and Transport Company; H. E. Hanson, Standard Oil Company (Indiana); P. E. Lakin, Shell Oil Company; Bernard L. Majewski, Deep Rock Oil Corporation; John W. Newton, Magnolia Petroleum Company; Will D. Parker, Phillips Petroleum Company; Arthur E. Pew, Sun Oil Company; M. H. Robineau, Frontier Refining Company; O. D. Robinson, Republic Refining Company; A. A. Stambaugh, Standard Oil Company (Ohio); C. B. Watson, The Pure Oil Company; Wayne C. Yeager, The Atlantic Refining Company, and William S. Zephrung, Pennzoil Company. Edwin S. Hall, American Petroleum Industries Committee, and Baird H. Markham, director of the committee, have been named as ex officio members.

Esso Researcher Sigma Xi Membership Committeeman

Dr. Minor C. K. Jones of Esso Laboratories of Standard Oil Development Company has been elected to the committee on membership of the Society of Sigma Xi. He is a member and former chairman of Esso Research Club, which is composed of technical research and development personnel of Standard Oil Company (New Jersey) affiliates. In 1943 this club became the first industrial research group affiliated with Sigma Xi.

Western Refiners Cancel Meeting Plans

Western Petroleum Refiners Association has cancelled plans for its annual meeting in the spring of this year. Decision of the board of directors was in keeping with curtailment of travel during the emergency.

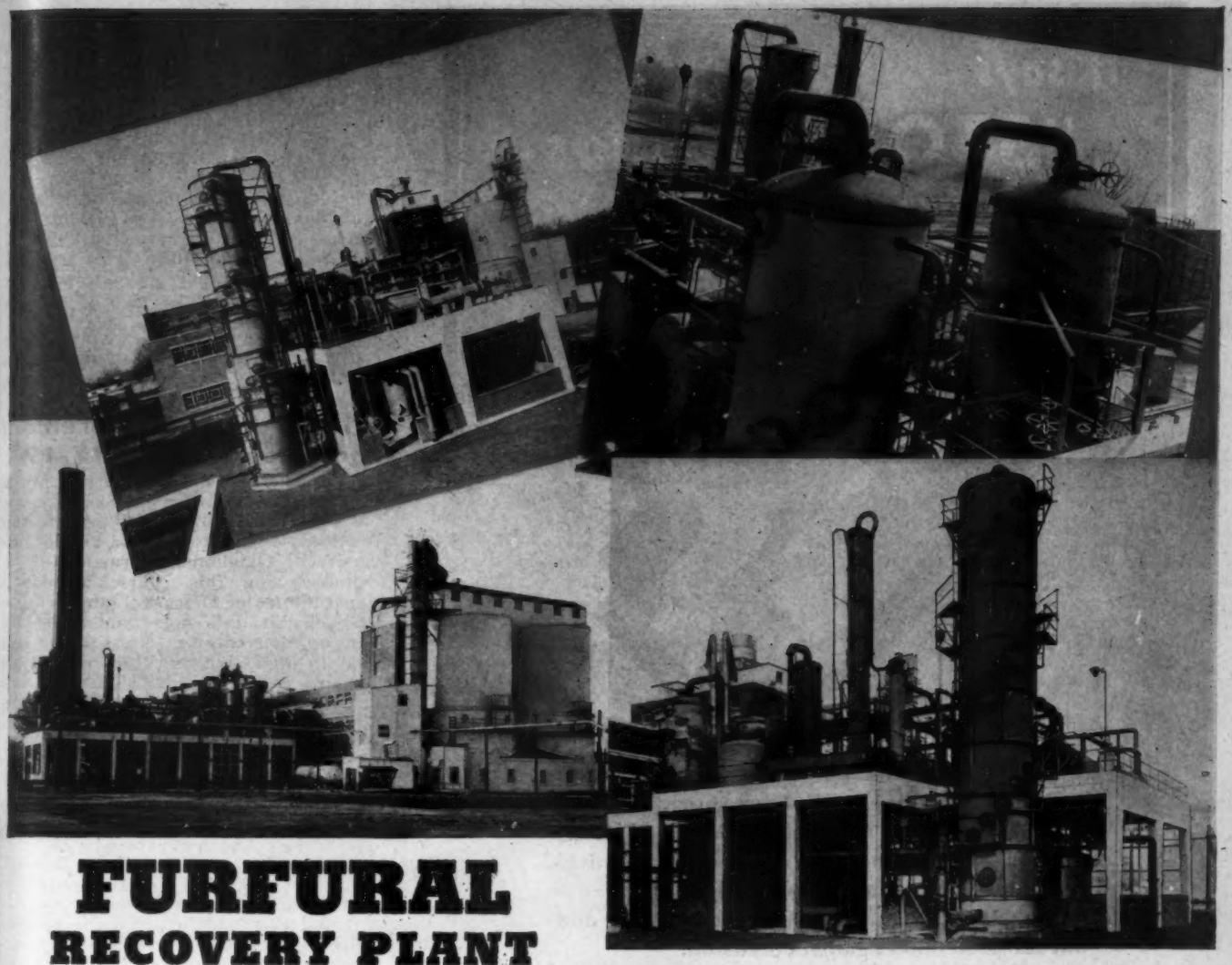
It was said that the board of directors will meet to transact necessary business, and the date for that meeting is to be announced.

Gas Meetings Cancelled

The executive board of the American Gas Association has cancelled nine meetings formerly authorized to be held between the dates of May 7 and June 4 including Natural Gas Convention, Cincinnati, Ohio, May 7-8; War Conference on Industrial and Commercial Gas, Toledo, Ohio, March 29-30; and Production and Chemical Conference, New York, June 4-6.

Federal Oil Taxes for January Register Gain

Revenue from federal oil taxes ran close to $37,000,000 in January and were $15,000,000 more than collections for the corresponding month last year, it was



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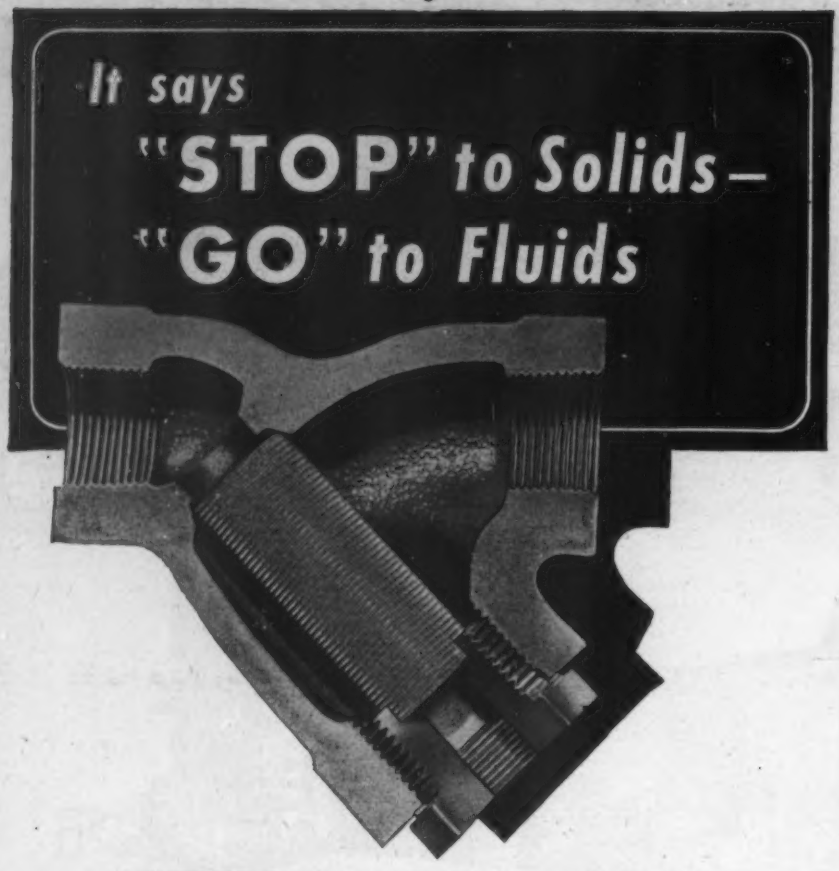

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YARWAY STRAINERS

reported by the Internal Revenue Bureau February 27.

Gasoline-tax collections for the month amounted to $28,919,880, against $17,068,957 a year ago, while receipts from lubricating oils amounted to $6,827,325 compared with $3,370,483 and pipe-line transportation paid $1,084,607 compared with $1,094,154.

For the first seven months of the fiscal year, revenue from the gasoline tax reached $231,924,319, an increase of $69,231,720 over the $162,692,599 recorded for the corresponding period a year ago; lubricating oil receipts were $46,194,752 against $28,928,450, an increase of $17,266,302, and pipe-line taxes were $9,390,930 against $8,903,477, an increase of $487,813.

Will Hold Gas Measurement Short Course April 17-19

The general committee of the Southwestern Gas Measurement Short Course has set April 17, 18 and 19 as dates for the 1945 session, to be held at the University of Oklahoma, Norman.

Recognizing this course as educational, Office of Defense Transportation has ruled it does not come under the ban on conventions. No session was held in 1943, but in 1944 registration was 524, and it was indicated this year's attendance may approximate that figure.

T. A. McDonald, First API President, Is Dead

Thomas A. O'Donnell, first president of the American Petroleum Institute, died in Los Angeles, February 20.

O'Donnell, 73, was born in Pennsylvania and went to California in 1893 to become a lease worker, later a contractor, and eventually entered the producing branch. He was president of American Petroleum Company (Doheny), and was active in developing the Coalinga, Midway-Sunset and Kern River fields of California.

O'Donnell helped organize the Independent Producers' Agency of California and during World War I he was in charge of production in the oil division of the U. S. Fuel Administration.

He became president of API on March 26, 1919, and held the office until December 11, 1924. On the latter date, at the fifth annual meeting of the Institute in Fort Worth, O'Donnell said oil reserves of the United States would last ten times ten years.

George H. Mettam Dead

George H. Mettam, assistant general manager of manufacturing operations of Standard Oil Company of New Jersey, died February 6 of a heart attack. He was 55. His association with the company's refinery operations covered 36 years, having started in 1907 in construction of Bayway refinery. In 1926 he was appointed mechanical superintendent of Bayonne refinery, and the following year became superintendent of the mechanical department. He became assistant general manager of manufacturing operations in June, 1940, and was elected a director of the company in March, 1941. On leave from May, 1943, to January, 1944, he served with Petroleum Administration for War in charge of refining in District 1. He also has been active in civic and philantropic affairs at Bayonne, where he made his home.

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DIGEST OF UNITED STATES PATENTS

On Polymerization of Hydrocarbons III

Compiled by HEINZ HEINEMANN

U.S.P. 2,336,005. Motor Fuel Production. F. E. Frey to Phillips Petroleum Company.

A combined polymerization and alkylation process is described, part of which deals with the dehydrogenation of isobutane to isobutene and a substantial portion of propene, which together with unreacted isobutane are subjected to catalytic polymerization.

U.S.P. 2,336,793. Conversion of Hydrocarbons. E. T. Laying, L. C. Rubin and R. F. Ruthruff to the Polymerization Process Company.

A catalyst for the polymerization of olefinic hydrocarbons is described which consists essentially of an intimate mixture of at least one metal pyrophosphate selected from metals of the group consisting of copper, mercury, zinc, magnesium, iron, aluminum and cobalt, and carbonaceous supporting material. The catalyst should be free of extraneous phosphoric acids and alumina or clays. Pressures up to 500 pounds and temperatures of 300-400°F. or more are employed. Charcoals, coke, pet residues and asphalt constitute suitable supporting materials. The amount of active pyrophosphate in the finished catalyst should not be substantially lower than 25 percent.

U. S. P. 2,338,741; 2,338,742; 2,338,743. Substituted Styrene-Polypiperylene Copolymer. F. J. Soday to United Gas Improvement Company.

A light oil ring substituted methyl styrene fraction obtained in the manufacture of oil gas is polymerized with a light oil piperylene fraction which has been previously polymerized catalytically with the aid of an acid acting metallic halid catalyst. From 50-99 percent of piperylene are copolmerized with from 1-50 percent substituted styrene to form a resinous composition. The piperylene may be replaced by isoprene or butadiene.

U.S.P. 2,342,400. Production of Polymerization Products from Ethylene. H. Hopff, S. Goebel and C. W. Rautenstrauch to General Aniline and Film Corporation.

Valuable heavy polmer products are obtained by polymerizing ethylene alone or admixed with other polymerizable organic compounds in an aqueous emulsion using oxygen or substances supplying oxygen as polymerization accelerators. Temperatures of 60-150°C. and pressures up to 1500 atm. are used. Suitable copolymerizable products are among others vinyl chloride, vinyl acetate, methocrylic acid esters, styrene, etc.

U.S.P. 2,344,213. Production of Polymerization Products from Isobutylene. M. Otto to The Alien Property Custodian.

When polymerizing isobutylene in the presence of Friedel-Crafts catalysts the polymerization is favorably influenced by working in the presence of small amounts of substances (accelerators) which are soluble in the reaction mixture under working conditions and which further have the property of being capable of dissolving boron trifluoride and which with BF_3 either form double compounds or hydrolyze the same with the intermediate formation of HF. The favorable action of these substances is evident also when employing other Friedel-Crafts catalysts such as $AlCl_3$, $FeCl_3$, etc. Suitable accelerators are monohydric alcohols, phenol and cresol. They are added in amounts up to 1 percent of the isobutylene. The reaction is carried out at below 10°C.

U.S.P. 2,344,950. Conversion of Hydrocarbons. W. B. Shanley to Universal Oil Products Company.

In the catalytic polymerization of olefins in a mixture of normally gaseous hydrocarbons consisting predominantly of C_3 and C_4 fractions, wherein the fresh charge stock supplied to the polymerization operation is relatively lean in C_4 fraction, the steps are claimed which comprise separating unconverted butanes from the liquid polymerization product and from unconverted propane, commingling butane thus recovered with the fresh charge stock, subjecting the resulting mixture to cooling and condensation, regulating the quantity of butanes thus recycled to insure substantially complete condensation of the propylene in the charge-stock mixture and supplying the resulting condensate to the polymerizing operation.

U.S.P. 2,345,574, Process of Polymerizing Unsaturated Hydrocarbons. R. E. Burk to The Standard Oil Company (Ohio).

A procedure to polymerize ethylene and propylene with boron trifluoride is described. BF_3 is employed in larger quantities than those commonly regarded as catalytic amounts, such as in a molar ratio of 1:1 or even greater BF_3: Olefin ratio. pressures of 50-720 pounds and preferably of 100-400 pounds are employed. Olefin is fed at —20° to 75°C. into the catalyst and cooling is provided to maintain the temperature at the desired level.

U.S.P. 2,347,182. Preparation of Polymeric Sulphides. D. D. Coffman to E. I. du Pont de Nemours & Company.

Polymeric sulphides of viscous to solid character are obtained by reacting a mixture of a dithiol and a diene hydrocarbon containing only thylenic unsaturation by subjecting the mixture to heat and continuing the reaction for at least 48 hours. The dithiol should have the general formula HSRSH in which R is a divalent hydrocarbon radical.

U.S.P. 2,348,017. Reaction of Hydrocarbons. O. N. Miller to Standard Oil Company of California.

A combined polymerization and alkylation process is described in the course of which isobutane, isobutene and butene-1 are polymerized under conditions tending to minimize loss of isobutane. The polymers are removed and the unconverted gas is alkylated with a butene-2 fraction.

U.S.P. 2,348,836. Catalytic Conversion of Hydrocarbons. R. E. Nagle to The Texas Company.

Olefinic hydrocarbons are polymerized at 375-400°F. with a phosphoric acid catalyst. A temperature differential of 50-60°F., increasing in the direction of the flow is maintained in the reactor and relatively cool, normally gaseous hydrocarbons are introduced to the reaction zone at a plurality of points to regulate the temperature differential. The water content of the hydrocarbon stream is increased as it advances through the reaction zone from 0.3 to 3.0 percent.

U.S.P. 2,349,904. Process for Preparing Catalytic Materials. K. H. Hachmuth to Phillips Petroleum Company.

A catalyst for the polymerization of low-boiling olefinic hydrocarbons heavier than ethylene is prepared from a hydrous gel of silicic acid, by treating the gel at least twice with an aqueous solution of a hydrolyzable salt of a metal selected from groups III B and IV A of the periodic system. Subsequent to each such treatment, the gel is washed with water, to free it substantially of soluble ionic matter and finally is dried at a temperature not substantially higher than approximately 225° F. and to a water content such that the resultant material is adopted to polymerize olefinic hydrocarbons in a concentration between 15 and 40 percent at a temperature of 200-225° F.

U.S.P. 2,350,330. Treatment of Hydrocarbons with Radio-Active Materials. Th. P. Remy.

A mixture of paraffins and olefins, such as can be found in petroleum oils is polymerized by treatment with a radioactive material, particularly of the thorium series. Uranium and radium materials also are useful. The radioactive material is finely distributed on a carrier such as fullers earth and mixed with the hydrocarbons at 160-265°F. and about 150 pounds pressure.

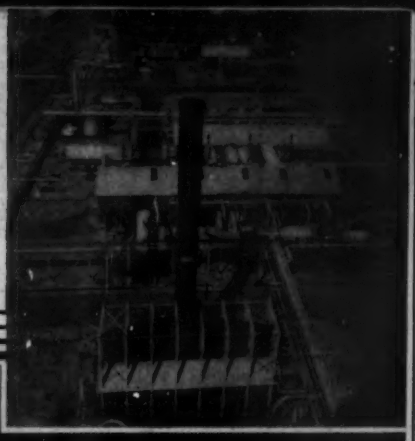
U.S.P. 2,351,123. Process for Preparing Hydrocarbons for Polymerization. H. L. Hays, J. L. Maher to Phillips Petroleum Company.

A gaseous mixture containing butanes, propenes, hydrogen and methane is polymerized after preceding separation and distillation to enrich the stock in C_3 and C_4 fractions.

U.S.P. 2,353,832.Catalytic Conversion of Hydrocarbons. L. C. Kemp to The Texas Company.

A continuous method for polymerizing normally gaseous olefins which com-

Aviation Gasoline Plants with Speed and Economy



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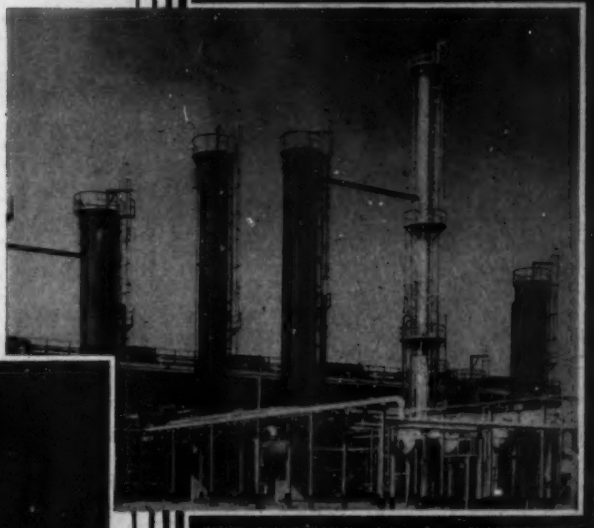

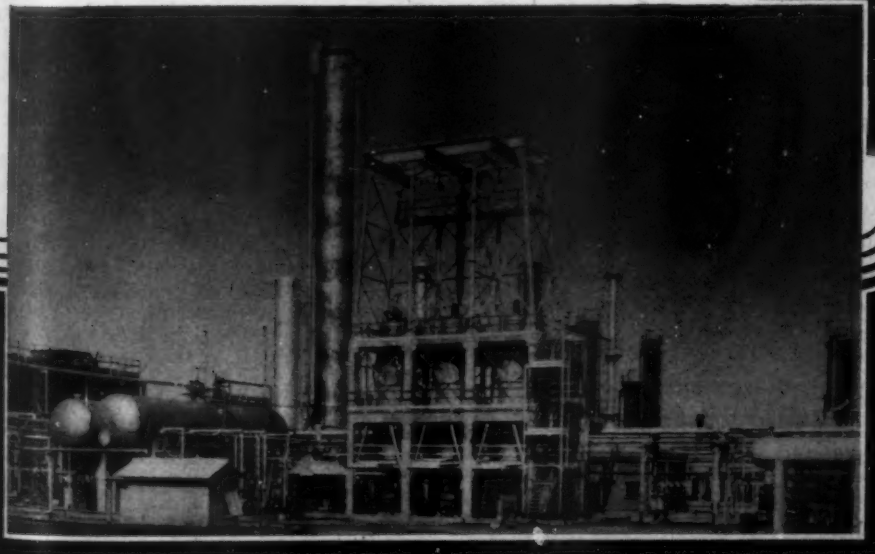

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prises heating a stream of normally gaseous hydrocarbons containing about 20 to 40 percent olefins to a temperature in the range about 375 to 400°F., continuously introducing said feed stream in vapor phase to a reaction tower packed with a solid polymerization catalyst comprising phosphoric acid having a concentration of about 100 to 110 percent H_3PO_4 by weight of the acid, passing said feed stream through the reaction tower from inlet to outlet, effecting polymerization of olefinic constituents of the feed to normally liquid hydrocarbons during passage through the reaction tower from inlet to outlet, said polymerization being accompanied by reduction in volume of said feed stream advancing through the reaction tower, injecting streams of hydrocarbon gas to the reaction tower at a plurality of succeeding points in the direction of hydrocarbon flow through the tower, adjusting the amount of gas so injected to compensate for said reduction in volume and thus maintain a substantially uniform velocity of hydrocarbon flow throughout the reaction tower from inlet to outlet, introducing a small amount of water in the feed hydrocarbon stream passing to the inlet portion of the reaction tower, injecting additional amounts of water to the reaction tower at a plurality of succeeding points in the direction of hydrocarbon flow such that the water content of the combined hydrocarbon stream passing through the outlet portion of the reaction tower is about 3 percent and maintaining the reaction temperature within the tower below about 475°F.

U.S.P. 2,354,261. Synthesis of Hydrocarbons. C. E. Hemminger to Standard Catalytic Company.

Relatively-low-molecular-weight hydrocarbons are polymerized to relatively heavier hydrocarbons in the presence of a powdered catalyst, which is used continuously under conditions such that the reaction takes place under elevated pressure and the product is adsorbed by the catalyst. The catalyst is removed to a separation zone, where the product is released from the catalyst at lower pressure. A surplus of catalyst, namely 2-10 parts per part of olefin is employed and the pressure in the reaction zone is kept between 100 and 400 pounds.

U.S.P. 2,355,392. Process for Treatment of Hydrocarbons. G. G. Oberfell to Phillips Petroleum Company.

Butadiene is separated from hydrocarbons with boiling points close to that of butadiene by polymerizing the diolefin at 300-900°F. and atmospheric to 500 pounds pressure in the presence of other hydrocarbons to the dimer, separating the dimer and depolymerizing it at 900-1300°F. in the presence of sufficient steam to maintain low partial pressure of the dimer.

U.S.P. 2,355,868. Catalytic Hydrocarbon Reactions and Catalysts Therefor. J. W. Jean.

A solid catalyst for polymerization reactions employing sulfuric acid is disclosed which comprises an inert support such as diatomaceous earth, kieselguhr, bentonite kaolin, fullers earth, etc., sulfuric acid of 93 percent concentration, a compound of boron and a metal oxide cementing agent. The ratio of atoms of boron to mols of sulfuric acid should be 1: 3.4. A good mixture will for instance consist of 1500 cc. of H_2SO_4, 500 g. boric acid and 600 g. of infusorial

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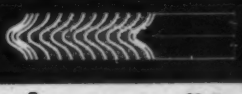
Type 4-Y 

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earth. About 500 g. of hydrated alumina are sufficient to harden the mixture.

U.S.P. 2,355,925. Polymerization Process. J. A. Reid to Phillips Petroleum Company.

In the production of hydrocarbons in the viscosity range of lubricating oils from low-boiling olefin hydrocarbons, in which the olefins are reacted in the presence of a metal-halide catalyst, the step to associate the active metal-halide catalyst with an alkali metal is described. There should be enough alkali metal present to react with all hydrogen halide and other impurities which have an adverse influence on the reaction. The alkali metal is unreactive as an olefin polymerization catalyst. The reaction temperature should not exceed 200°F.

U.S.P. 2,356,128; 2,356,129. Olefin Polymerization Process and Product. W. J. Sparks and R. M. Thomas to Jasco, Inc.

The invention presents a new interpolymerization in which an iso-olefin, preferably isobutylene or alternatively 3-methylbutene-1 is interpolymerized with a monomethyl substituted butadiene by subjecting the mixture of the olefin and the diolefin to the action of a dissolved active metal halide or Friedel-Crafts type catalyst at a low temperature, such as between —40° C. and —125° C.

U.S.P. 2,356,494. Polymerization of Cyclopentadiene Type Compounds. S. G. Trepp to the United Gas Improvement Company.

In a process for catalytically polmerizing an unsaturated compound selected from the group consisting of cyclopentadiene and alkyl substitued cyclopentadienes, having the cyclopentadiene nucleus containing the characteristic conjugated double bonds in the substantial absence of compounds of other types polymerizable under the conditions obtaining wherein substantially undiluted gaseous BF_3 is employed as catalyst, the steps of preventing the total formation of benzene-insoluble polymers are claimed, comprising thoroughly agitating the reaction mass while maintaining the reaction temperature not in excess of 100°C., maintaining the concentration of said unsaturated compound not in excess of 11 percent by weight, maintaining the proportion of catalyst to said unsaturated compound not in excess of 10 percent by weight, and stopping the reaction while benzene-soluble polymer is present in the reaction mass.

U.S.P. 2,356,700. Treating Hydrocarbon Fluids. W. H. Rupp and C. T. Harding to Standard Oil Development Company.

A reactor is described which may be used in nonselective catalytic polmerization and which may be easily converted to selective polymerization of olefins. Better temperature and longer catalyst life are obtained than previously possible. According to the invention a core is introduced into the reaction tube and catalyst is introduced into the reactor around the core to form an annular bed of catalyst granules or pills. By varying the size of the core the thickness of the catalyst bed may be varied to obtain desired temperature control during the reaction.

U.S.P. 2,357,926. Polymerization. L. A. Bannon to Standard Oil Development Company.

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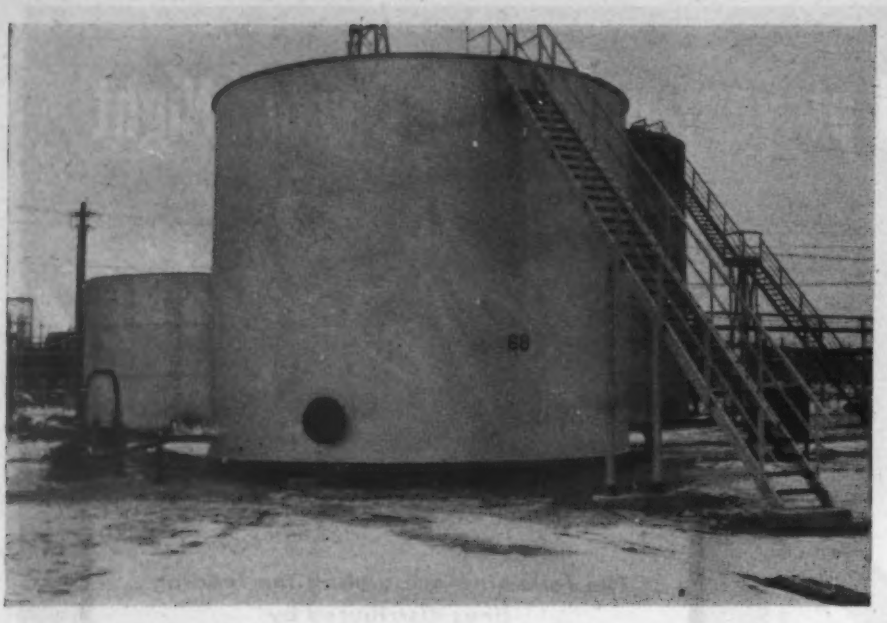

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merized to a product with a viscosity at least as high as that of a lubricating oil in the presence of a liquid catalyst consisting of boron trifluoride and water in a proportion of 1: 5 mols. The reaction temperature is below 40°C. and pressure of 1-50 atmosphere is employed.

U.S.P. 2,360,632. Process for Preparing Polymers of High Molecular Weight. M. D. Mann and L. B. Turner to Jasco, Inc.

Polymers prepared from an iso-olefin by contact with a Friedel-Crafts catalyst at a temperature below —10°F. are often rather dark in color and develop color rapidly upon heating. This is avoided by contacting the polymerization products with an alkali mixed with a hydrocarbon oil before the temperature of the polymerization product is permitted to rise above about —10°F.

U.S.P. 2,362,311. Polymerization of Olefins and Catalysts Therefor. L. C. Rubin to The Polymerization Process Company.

Olefins are polymerized at elevated temperatures with a catalyst comprising an intimate mixture of a metalpyrophosphate capable of reduction to a polymerization catalyst (such as copper, mercury, zinc, magnesium, iron, aluminum, cobalt pyrophosphate) and a metal phosphate not capable of ready reduction (such as calcium phosphate). The mass is used in granulated form.

John W. Thomas Gets Chemists' Medal Award

The Gold Medal award of the American Institute of Chemists will go to John W. Thomas in formal presentation planned for May 11, during the institute's annual meeting at Columbus, Ohio. Thomas is chairman of The Firestone Tire & Rubber Company, and the medal is given in recognition of his leadership in rubber research for four decades, and for achievements under his direction in the development and production of synthetic rubber.

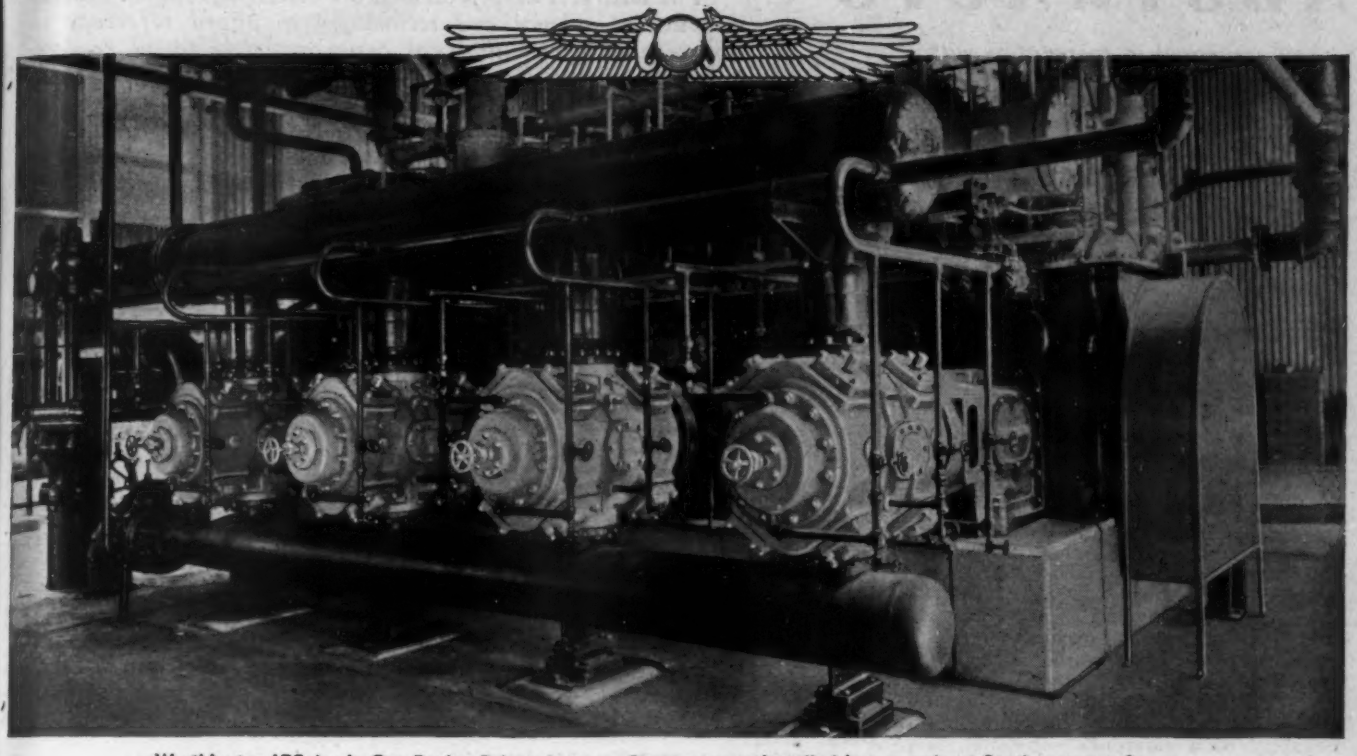
Thomas received his degree in chemistry at Buchtel College (now Akron University) in 1904, and installed the first chemical laboratories for The Firestone Tire & Rubber Company in 1908. He since has taken an important part in establishing chemical research as a major arm of industry. As an executive he has been instrumental in translating research results into production, notably evidenced in his part in building the synthetic rubber industry during the war period. During the past year he has supervised design and construction of a modern and complete rubber-research laboratory soon to be opened by his company.

The jury of chemists making the award included Dr. Gustav Egloff, president of the institute; Dr. Harry L. Fisher; Dr. Robert J. Moore; Dr. Maximilian Tock, and Howard S. Neiman.

New Owner Will Enlarge Wynnewood Refinery

Assets of Cosco Oil Company, including a 2300-barrel refinery at Wynnewood, Oklahoma, have been purchased by Fen-Ter Refining Company, wholly-owned subsidiary of Kerlyn Oil Company of Oklahoma City. The purchaser has announced plans for doubling capacity of the plant.

HOW TO FIT AN ANGLE GAS-ENGINE COMPRESSOR EXACTLY TO YOUR REFRIGERATION JOB



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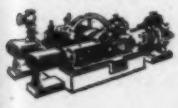
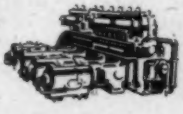
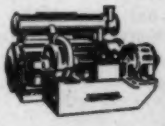


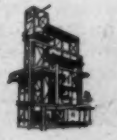
2. Angle engine compressors



3. Centrifugal compressors



4. Absorption refrigerating machines



5. Chilling machines and exchangers

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Representation of Equilibrium Constant Data. E. G. SCHEIBEL AND F. J. JENNY. *Ind. & Eng. Chem.* **37** (1945) pp. 80-82.

The authors present a nomograph giving the equilibrium constant data for hydrocarbon solutions. It is claimed that it covers a wider range of temperatures and pressures with greater accuracy than previous nomographs. The construction of the chart is completely empirical, with the calibration of the temperature scale based on the liquid fugacity of a reference substance and the pressure scale based on the vapor fugacity of a reference substance. The nomograph is useful in the calculation of bubble points, dew points, and equilibrium flash vapor composition on hydrocarbon solutions in that a single setting gives the value of the equilibrium constants for all the components. The chart covers hydrocarbons from methane to tetradecane. The authors review the merits of previously-constructed charts and describe the construction of their own nomograph, giving sources of procedure and data used. A bibliography of 9 references is included.

The Liquid State. J. H. HILDEBRAND. *Proc. Phys. Soc.* (London) **56** (1944) pp. 221-39.

A general survey of recent experimental work and of theoretical conclusions on the liquid state is presented. Trouton's entrophy rule is discussed in detail with organic applications. The effect of the dipole moment upon departures from the rule is discussed. Large departures are found in those cases in which the dipole moments are capable of associating the hydrogen bonds or bridges. The effects under consideration are demonstrated by curves giving the change in molar polarization on going from dilute solutions in nonpolar solvents to concentrated solutions where there is interaction in the response to the external field. Solubility curves for iodine in a variety of solvents are given. The effect of the dipole moment on Raoult's law is considered. The o-, m- and p- dinitrobenzenes show that the dipole moment has little effect. Deviation from Raoult's law depends only upon the number, and not on the position, of the nitro groups. Using anthracene and phenanthrene in benzene solution as samples, it is shown that, in general, increase in solubility depends much more on hydrogen bridges than on dipole moment.

Liquid-Vapor-Equilibrium in Methane-Ethylene-Isobutane Systems. M. BENEDICT, E. SOLOMON, AND L. RUBIN. *Ind. & Eng. Chem.* **37** (1945) pp. 55-59.

In a previous paper the authors proposed an empirical equation for prepicting the P-V-T properties, vapor pressures, and critical properties of pure light hydrocarbons. This equation was later extended to solutions of light hydrocarbons, and methods were proposed for determining the parameters in the equation for solutions from the parameters of the individual hydrocarbons. To provide a more rigorous test for the equation in its application to solutions, experimental liquid-vapor equilibrium data were obtained for the ternary system methane-ethylene-isobutane at 37.78° and 71.11°C. and at 34.02 and 68.05 atmospheres. The preparation of the materials used is described, as well as the apparatus and method of procedure used in the work. The results are presented in some detail in tabular and graphical form. The data are shown to be in satisfactory agreement with the predictions of the authors' equation, and they conclude that the equation of state appears to be as satisfactory for calculating distribution soefficients in ternary solutions of light hydrocarbons as for binary solutions. Also, its applicability to solutions containing olefins is considered as confirmed.

Chemical Compositions and Reactions

The Preparation of 1,3- and 1,4-Pentadienes from Furfural. L. E. SCHNIEPP AND H. H. GELLER. *Jour. Amer. Chem. Soc.* **67** (1945) pp. 54-56.

The thermal decomposition of 1,5-pentanediol diacetate presents an attractive method of preparing 1,4-pentadiene. The pure diene was obtained in yields of 90-96% by cracking the diacetate at 575 ± 5°C. Nearly quantitative yields can be obtained by recycling the cracked material until all of the acetates have been converted. The conversion of 1,2-pentanediol diacetate to 1,3-pentadiene averaged 60-65% of the theoretical yield. The diol compounds used are obtained as hydrogenation products from furfural, therefore the methods studied provide a means of converting furfural to pentadiene. A new compound, pentene-1-ol-1 acetate was isolated and characterized. It was shown that in general the pyrolysis of the pentanediol diacetates proceeds through the intermediate pentene-ol acetates.

Research of Aromatics in the Presence of Dehydrogenation Catalysts. 1. Action of Chromia-Alumina on Benzene, Toluene, Butylbenzenes and Bibenzyl. W. J. MATTOX AND A. V. GROSSE. *Jour. Amer. Chem. Soc.* **67** (1945) pp. 84-86.

Recent investigations in the conversion of various types of hydrocarbons to aromatics by the action of dehydrogenation or aromatization catalyst have raised the question as to what action such catalysts exert on the aromatic hydrocarbons formed. The present paper is a report on an investigation of this phase of the subject. The action of chromia-alumina on benzene, toluene, n-butylbenzene, p-di-n-butylbenzene, phenyl-n-propyl ketone and bibenzyl at 500-600°C. was investigated. Biphenyl and anthracene were formed from benzene and toluene, respectively, without the formation of detectable amounts of other aromatics. Naphthalene yields of 51-55 weight percent per pass were obtained from n-butylbenzene. Similar dehydrogenations with p-di-n-butylbenzene gave pehanthrene yields of 14-18 weight percent per pass. Anthracene was not formed in any substantial quantity. Dehydrogenation of phenyl n-propyl ketone resulted in the formation of naphthalene to the extent of 34 weight percent per pass at 600°C. Dehydrogenation of bibenzyl resulted in the formation of stilbene without the formation of phenanthrene or anthracene.

The Effects of Temperature on the Polymerization of Styrene. S. G. COHEN. *Jour. Amer. Chem. Soc.* **67** (1945) pp. 17-20.

The author studied the polymerization of a typical vinyl compound, styrene, as catalyzed by benzoyl peroxide. Polymerization was studied at three temperatures at equal rates of peroxide decomposition. The rates of polymerization and the molecular weights of the products increased under these conditions with rise in temperature of reaction, the rates rising more rapidly than the molecular weights. The activation energy of

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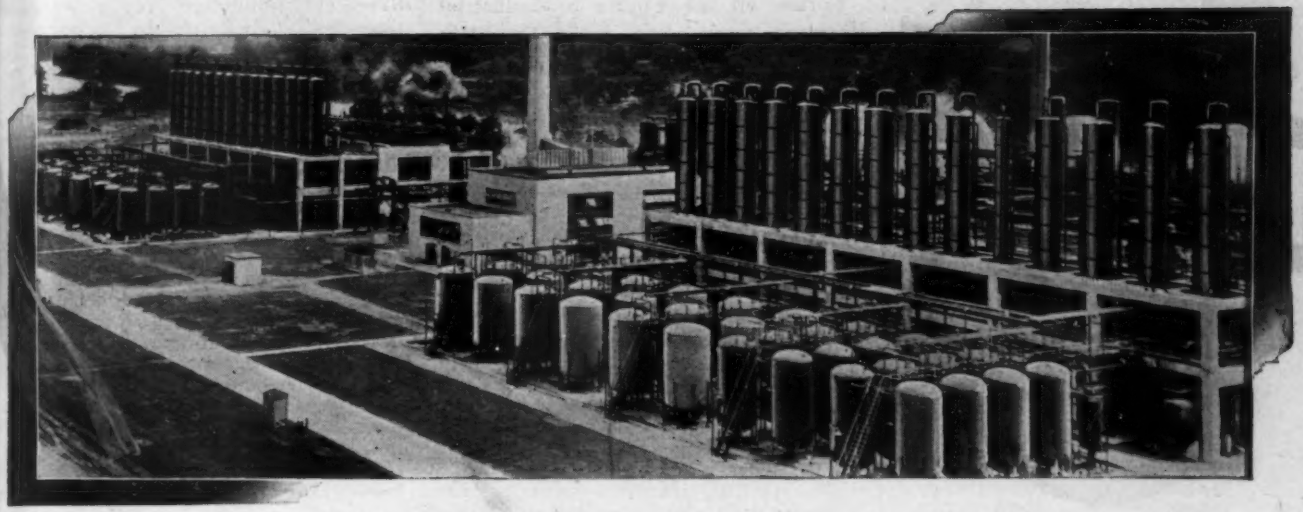

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the chain growth reaction was estimated to be 11 kilogram calories. This calculation was based on the approximation that at equal rates of peroxide decomposition at several temperatures there are equal rates of chain initiation. It was concluded that, in the peroxide catalyzed polmerization of styrene, the molecular weight is determined largely in a reaction of lower activation energy than that of chain growth, and chain transfer reactions are of minor importance. This is in general agreement with the conclusions of other and previous investigators. The rates of decomposition of benzoyl peroxide in 3.46 molar solutions of styrene in benzene were determined at 53.98, 64.02 and 74.02°C.

Forum on the Future of Industrial Research. *Chem. Eng. News* **22** (1944) pp. 1752-79.

The article is a report on a forum organized by the Standard Oil Development Company on the occasion of its 25th anniversary. Two questions were primarily under consideration: (1) What should be the guiding principles and objectives for the commercial programs of industrial research and development organizations? (2) How can small business serve itself and be served by industrial research and development? Several papers were presented and covered such subjects as "The Physicist's Point of View," "The Chemist's Point of View," "The Views of Industrial Management," "Research by the Business Itself," "Research by Trade Associations and Cooperative Groups," "The Growth Factor in Small Business," "How the Research Foundation May Serve Small Business," "Research by Government and Its Value to Small Business," and "Research in Relation to National Security."

Manufacture: Processes and Plant

The Design of Class 1 Pressure Vessels. E. J. HEELEY. *Industrial Chemist,* **21** (1945) pp. 16-22.

The development of code requirements for Class 1 pressure vessels is briefly sketched and a comparison of the requirements of several codes for particular cases is given. Differences between the codes as to permissible working stresses at Class 1 welded joints is occasioned by differences in the major factors involved such as the diameter used, the lower limit of tensile strength of the plate material, the so-called "efficiency factor" for the welded joint, and "correction factor." The influence of tensile strength, efficiency factor, and the fixed correction factor are discussed. The physical properties determined by mechanical tests ordinarily applied in assessing the quality of welded seams do not provide an indication of the behavior of the welded joints under the influence of the varying stresses imposed under operating conditions. Recourse must therefore be made to tests carried out under fluctuating, as distinct from steady, test conditions to assess the strength of the welded joints. The effect of discontinuities is considered. Divergence from truly circular form is briefly discussed. A formula for the relationship between maximum working pressure, diameter, and wall thickness is given, which the author considers would give the much needed simplification in the design of Class 1 welded pressure vessels. Attachment of the heads and of flanges and branches is briefly considered.

New Basis Developed for Comparing Heat Transfer Fluids. P. W. PARSONS AND B. J. GAFFNEY. *Chem. & Met. Engr.* **52** No. 1 (1945) pp. 100-104.

The authors have developed a method for comparing various fluids as heat transfer media when the fluids are heated or cooled inside tubes, wherein the power to circulate the fluid is related to the film coefficient that results. It has long been known that increasing the energy used for circulation increases the heat transferred. The method outlined makes it possible to rank various media according to merit as heat transfer agents. The development of the relationship used as criteria is outlined in detail and the use of the relationship explained. Typical heating or cooling fluids are listed in accordance with their value as heat transfer media. In general its is possible to operate so that the fluid flows in the streamline region, for not only is there a considerable increase in film coefficient on passing from streamline to turbulent flow, but, also, equal percentage increments in energy are more effective in increasing the film coefficient in the turbulent region. A bibliography of 37 references is included.

The Use of Azeotrope-Forming Substances in the Separation of Light Hydrocarbon Fractions from the Corbonization of Coal into Aromatic, Saturated, and Unsaturated Constituents. II. Separation of Saturated Hydrocarbons and Styrene from Xylole Fractions. E. A. COULSON, E. C. HOLT, AND A. SLEVEN. *Jour. Soc. Chem. Ind.,* **63** (1944) pp. 333-36.

Rich fractions containing about 50% styrene can be separated from crude coal-tar naphthas by efficient fractionation at reduced pressure. Pure monomeric styrene and xylene can be separated fairly completely from these fractions by azeotropic fractional distillation at normal or reduced pressures using ethylene glycol monomethyl ether as the third component in a column equivalent to 36 theoretical plates. The amount of styrene separated from typical crude naphthas was 1.5-1.8% and from a typical solvent naphtha 7.3%. Saturated hydrocarbons present in the xylole fractions and of boiling points close to those of the xylenes can be separated with much greater ease by azeotropic fractionation using the same azeotrope-former.

The Use of Azeotropes in the Separation of the Aromatic, Saturated, and Unsaturated Constituents of Hydrocarbon Fractions from the Carbonization of Coal. Part I. Separation of Benzene and Toluene from Vertical-Retort Toluols. E. A. COULSON AND E. C. HOLT. *Jour. Soc. Chem. Ind.,* **63** (1944) pp. 329-33.

It is well known that many pure hydrocarbons of the paraffin type form azeotropes of minimum boiling point

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Whitlock radiator coils on Columbia Racing Car driven by Eddie Bull (Cannonball) at Charter Oak Park, 1906. Photo courtesy Haniss Collection, Hartford, Conn.

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The Moore-Charlton Proportiometer Pump. Editorial, *The Industrial Chemist,* 20 (1944) pp. 673-75.

The pump described was originally designed for use in the oil-refining industry. for the injection of chemicals into the transfer lines in continuous distillation plants, and for the dosing of continuous treatment units. The pump is a positive displacement pump in which the quantity of liquid delivered can be varied from zero to full capacity, while the mechanism is operated at constant speed. Setting of the rate of delivery can be made while the pump is in motion. The pump is a precision instrument made for the most exacting conditions. The pump is fitted with a pointer that indicates the delivery rate on a dial on the gear unit. Three sizes are available, using 1, 5, and 10 h.p. motors. The largest pump has a maximum output of 17.5 gallons per minute at 475 pounds pressure. The pumping capacity is varied by alternating the phase relation of the two plungers. When the pistons are in phase the capacity is a maximum. When they are 180° out of phase the pumping capacity is zero. The rotary motion of the drive is changed into reciprocating motion of the pistons by means of a yoke and slipper so that the piston movement is true simple harmonic motion.

China Produces Fuels from Vegetable Oils. FA-WU CHENG. *Chem. & Met. Engr.* 52 No. 1 (1945) p. 99.

In 1937 China turned to tung and other vegetable oils as a source of fuels, and since that time has erected several plants for cracking them into gasoline and other liquid fuels. Atmospheric and high pressure processes are used, either direct or catalytic, and either liquid or vapor phase. Only the fatty acids undergo decomposition, glycerin playing little part. Pressures of 50 to 150 pounds per square inch are used in the pressure processes, the temperatures range from 400 to 500°C. From 100 pounds of tung oil about 75 pounds of crude oil is obtained, of which approximately half is a light spirit. This is refined in accordance with practices usual for gasoline. The other half of the oil may be refined into kerosene or Diesel and lubricating oils, or recracked to obtain additional gasoline. The properties of typical products are described in tabular form.

Products: Properties and Utilization

Measuring the "Existent Corrosivity" of Used Engine Oils. R. G. LARSEN, F. A. ARMFIELD AND L. D. GRENOT. *Ind. & Eng. Chem., Anal. Ed.* 17 (1945) pp. 19-24.

Because of efficient and compact design, engines are constructed today that give more power per unit weight than previously. Bearings are smaller and are required to carry heavy loads and operate at higher temperatures. Metals used in bearings are more susceptible to chemical attack. This has led to bearing failures, but lubricants now produced give improved performance in many ways and give the engine designer greater latitude. Improvement in oil performance has generally been accomplished through the use of additives. The purpose of the present work was to develop a simple test that would give a reliable indication of the corrosivity of used oil and which could be used as a guide by the engineer in determining the cause of bearing failures, and by the operator to decide when an oil change is necessary. A test for existent corrosity makes use of test strips coated with lead or other metal in graduated thicknesses and measures a property of used oils not heretofore satisfactorily measured by routine engine oil tests. The preparation of the corrosion test strips is described. The data secured in the work are presented in considerable detail in tabular and graphical form. The application of the method to practice is briefly considered. A bibliography of 13 references is included.

Corrosion of Metals by Organic Acids in Hydrocarbon Solvents. C. F. PRUTTON, D. R. FREY, D. TURNBULL AND G. DLOUHY. *Ind. & Eng. Chem.* 37 (1945) pp. 90-100.

The purpose of the investigation reported in the paper was to evaluate the most important factors involved in bearing corrosion and to discuss the mechanism of the corrosion reaction. The presence of oxygen or peroxides is a necessary condition for the corrosion of lead and cadmium by fatty acid solutions in hydrocarbon solvents. Although corrosion in these media will not take place to any large extent in the absence of acids, the rate of corrosion is mainly controlled by the rate of diffusion of oxidizing agent into the metal surface and by the chemical rate of oxidation of the metal rather than by acid strength or concentration. When an insoluble soap film is formed on the metal surface, the rate of corrosion is controlled by the rate of diffusion of the oxidizing agent through the film. Accumulation of lead soaps in solution markedly decreases the rate of corrosion of lead. When dissolved oxygen is used as the oxidizing agent in the corrosion of lead, the limiting rate of corrosion varies directly with oxygen pressure and may be represented as a function of tempera-

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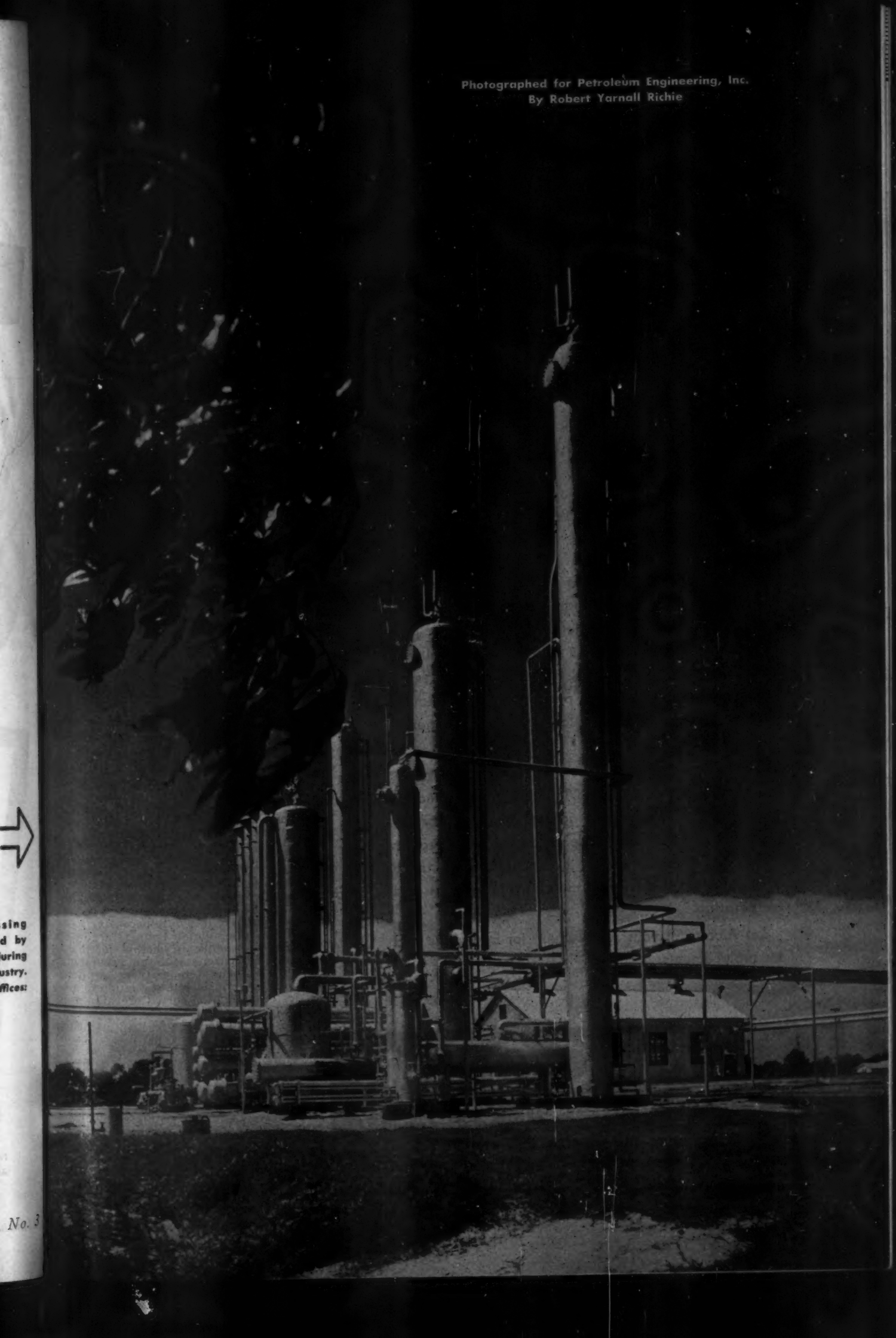

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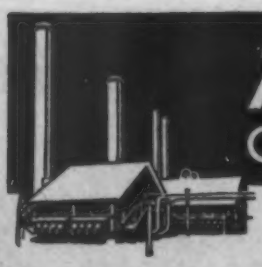

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ture by the Arrhenius equation. Corrosion of lead becomes rapid around 40°C. and corrosion of cadmium around 80°C. Corrosion of lead proceeds at about the same rate in benzene as in xylene solutions, but much more slowly in white oil solutions because of the relatively high viscosity of white oil. Corrosion of bearing metals by lubricating oils containing fatty acids may be caused by dissolved oxygen and by organic peroxides. At temperatures above 100° C., corrosion of lead in white oil due to dissolved oxygen becomes much smaller than at 100°C. or lower. At higher temperatures corrosion of bearing metals by acidic oils is probably caused principally by organic peroxides, as has been suggested by Denison. Data secured in the course of the work are presented in considerable detail in tabular and graphical form.

Miniature and Micro Suspended Level Viscometers. M. M. LAPITZKY AND S. THOMPSON. *Jour. Inst. Petr.* **30** (1944) pp. 349-50.

A viscometer is described for use in the determination of viscosity when only a small quantity of oil is available. The case in point is the determination of the K.V.I. of the mineral-oil portion separated from compounded oils or greases. The usual suspended level viscometer requires about 20 cc. of oil for a determination, whereas the quantity normally available for compounded oils or greases rarely exceeds 5 cc., and is usually of the order of 2 cc. The design described is based on the Fitzsimons modification of the Ubbelohde suspended level viscometer. Miniature and micro viscometers have been constructed, the former requiring 5 cc. and the latter as little as 2 cc. of oil, although retaining the accuracy prescribed by standard methods. The typical instruments are pictured and dimensions given. A table showing typical results obtained on normal and micro types of viscometers is appended.

Ternary Mixtures of Three Isomeric Heptanes. V. A. MILLER. *Ind. & Eng. Chem., Anal. Ed.* **17** (1945) pp. 5-12.

The author describes a method based on a refinement of the solution temperature of the hydrocarbon mixture diethyl phthalate and nitrobenzene by which the composition of a mixture containing 2, 4- and 2,, 2-dimethylpentane with 2, 2, 3-trimethylbutane can be determined quantitatively, the first two components within 3% and the last component within 0.3%. This particular mixture of heptanes is the one that boils at about 80°C. To analyze the ternary mixture quantitatively it is only necessary to determine the solution temperature of the unknown sample in diethyl phathalate and nitrobenzene with an accuracy of ±0.01°C. The temperatures so determined are considered in relation to a series of calibration curves prepared using mixtures of known composition. The entire analysis requires approximately one hour. The history of the application of critical solution temperature measurements to hydrocarbon analysis is briefly reviewed. A search was made for suitable solvents for the determination of critical solution temperatures. Ninety-seven compounds were investigated, and of these twelve were selected for further study. The apparatus used in the work is described in some detail, as well as the procedure used in the experimental work. The data obtained in the course of the work are presented in detail in

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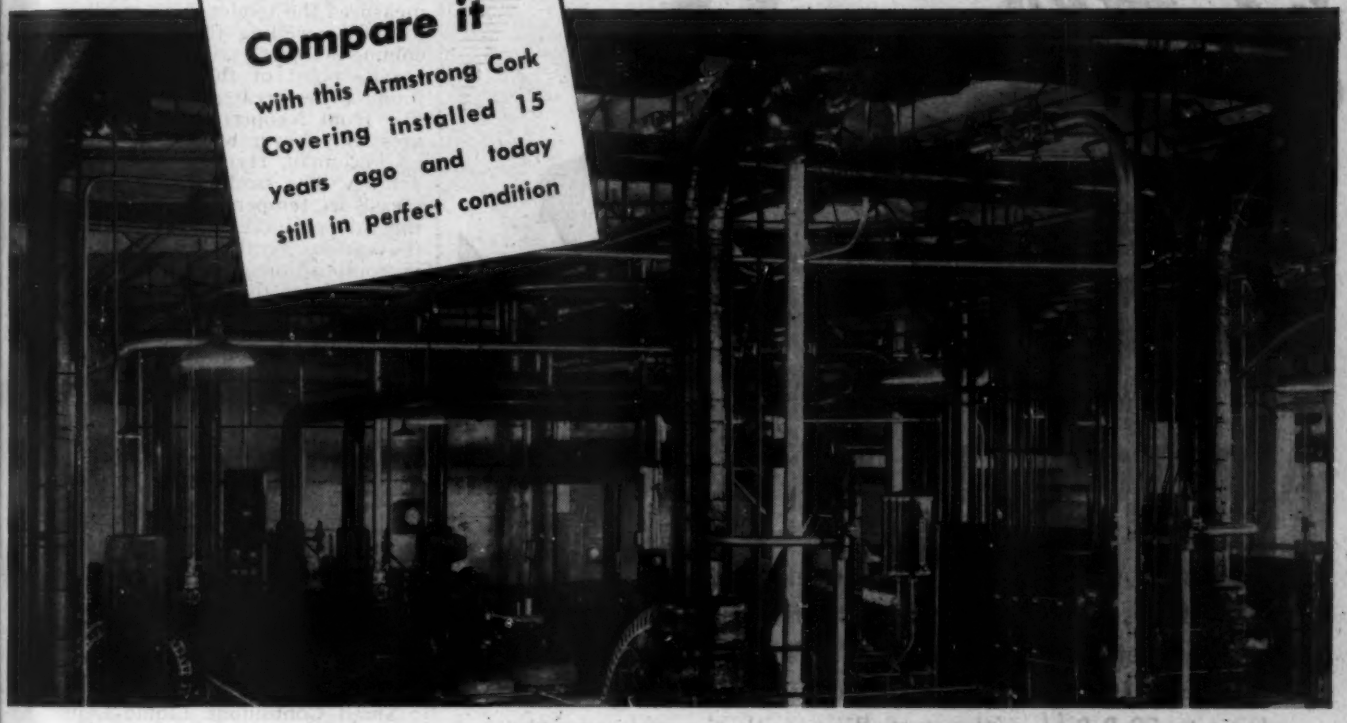

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Armstrong's Cork Lagging installed on shell cooler at Security Warehouse, Santa Clara, Cal., in 1929 at the same time as the cork covering shown above. The photographs were taken June 1944.

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tables and also in graphical form. A bibliography of 34 references is appended.

Swelling of Synthetic Rubbers in Mineral Oils. P. O. Powers and B. R. Billmeyer. *Ind. & Eng. Chem.* **37** (1945) pp. 64-67.

The swelling of compositions from typical oil-resistant rubbers was measured in hydrocarbons having a wide range of solvent power. Compositions loaded with the same volume of SRF carbon black and no extractable softeners were studied at 25°, 70°, and 100°C. The aniline point of the hydrocarbon measures the tendency to swell, and up to 100% swelling the logarithm of the volume increase varies inversely with the aniline point of the oil. Swelling was found to be greatest with the composition from Neoprene GN and was progressively lower with those from Stanco Perbunan, Hycar OR-15, and Thiokol FA. The swelling was found to increase as temperature was raised, but the rate of increase was different with the various synthetic rubbers. Changes in composition during test may be responsible for these differences. Consideration of these results and published data indicates that the slope of the log swelling-aniline point plots of compositions from a particular synthetic rubber does not change with temperature, loading, or degree of cure. There is apparently a small difference in the slope as the type of synthetic rubber is changed. Tensile strength, elongation, and durometer readings of the swollen compositions show a decrease with increased swelling, a slight decrease at 10%, and a very pronounced drop at 100% swelling. Thiokol compositions have little strength when immersed at 100°C. Data are presented in tabular and graphical form, and a bibliography of 11 references is appended.

Small Continuous Liquid-Liquid Extractors. M. Wayman and G. F. Wright. *Ind. & Eng. Chem., Anal. Ed.* **17** (1945) pp. 55-56.

The authors describe two designs for extractors for solvents lighter than water and one design for solvents heavier than water. These have been found useful for handling small quantities of solutions to be extracted by immiscible solvents, their use being attended by a saving in time as against successive batch extraction and also avoidance of losses.

Determining Oxygen in Hydrocarbon Gases. K. Uhrig, F. M. Roberts and H. Levin. *Ind. & Eng. Chem., Anal. Ed.* **17** (1945) pp. 31-34.

A study of refinery operations to discover factors affecting catalyst life indicated the importance of methods for determining small quantities of oxygen in hydrocarbon gases. A method is described for determining oxygen in concentrations of 0.001 to 5.0%. The oxygen is made to react with copper wetted with ammonia-ammonium chloride solution, the resulting mixed oxides are dissolved in the same solution and reduced to cuprous form. Copper is determined iodometrically as a measure of oxygen in the sample. The method gives accurate results when applied to saturated and unsaturated hydrocarbon gases. Sulfur dioxide, hydrogen sulfide, and mercaptans must be removed and means for doing so are described. The method

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in general is based on well-known reactions but modifications have been made in technique and equipment. The apparatus used is described in some detail and is shown in diagrams. Typical results are presented in tabular form. A bibliography of 15 references is included.

Automatic Laboratory Fractionating Column. V. C. SMITH, A. L. GLASEBROOK, C. R. BEGEMAN, AND W. G. LOVELL. *Ind. & Eng., Chem., Anal. Ed.* **17** (1945) pp. 47-52.

An automatic laboratory fractionating column, one of a number used for some years by the Research Laboratories Division of General Motors Corporation for the analytical distillation of close-boiling hydrocarbons, is described in detail. It is made almost entirely of corrosion-resistant metal, including a 10-foot vacuum jacket. The automatic features include control of heat input to the still pot, collection of the distillate in separate containers, and recording the volume of distillate and the distillation temperature. Adequate safety features are provided. Using a modified removable Dufton packing, the column has 50-ml. holdup, 1200-ml. per hour throughput, and as high as 120 theoretical plates. Detailed drawings of the column and auxiliaries, and of the electrical circuits for automatic control are presented in the article. Typical distillation curves are given showing the separation of a solution containing all five hexane isomers, and also several single branched hexenes. The data as presented indicate the separation of pure compounds from these solutions. Little attention is required, for instance, one man operated six columns as part of his work.

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd, Federal and Dearborn Streets, Chicago 16, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only in one gram quantities, please inform the Registry.

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1,2-Diethyl benzene
1,3-Diethyl benzene
1,4-Diethyl benzene
Di para tert butylbenzene
Di para tert amylbenzene
1-n-Dodecyl benzene
1-Amino-9-octadecene
2- or 4-Benzyl benzoic acid
1,4-Dichloro-2-methyl butane
Dihydro alpha dicyclopentadiene-3-one
Distearyl ketone
Glycidol
Hexanone-3
Margyryl methyl ketone
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Book Reviews

The Modern Gas Turbine

By R. Tom Sawyer. Prentice-Hall, Inc., New York. Price $4.00.

This book discusses the gas turbine as an effective super-charger drive for diesel and other internal-combustion use, as well as prime mover for station and transportation use. The book is well illustrated with diagrams outlining the various systems of supercharging and utilization of the hot gases in turbine units, and with line diagrams of the various types of prime movers in which the hot gases are used.

The book is written for the non-technical reader, and is free of the involved mathematical computations which usually accompany a discussion of the heat-cycle and its employment for power generation. The discussion is brought up to date, some of the citations being from 1944 issues of magazines, and probably represents the latest word on the development of what many engineers regard as the coming prime mover.

National Fire codes for Flammable Liquids, Gases, Chemicals and Explosives

592 pages. National Fire Protection Association, 60 Batterymarch Street, Boston, Massachusetts. Price $3.00.

This book assembles standards dealing with fire and explosion hazards. Superceding the National Fire Codes for Flammable Liquids, Gases, Chemicals and Explosives for 1943, the new volume contains information on new chemicals and solvents used in war industries, including information on their fire hazard properties and the best method of fire extinguishment. In addition, there are six new or revised codes.

This new volume is divided into nine parts as follows: Flammable Liquid Storage and Handling; Oil and Gasoline Burning Equipment; Liquefied Petroleum Gases; Utilization of Flammable Liquids; Gases; Refrigeration and Fumigation; Explosives and Nitrocellulose Materials; Tables of Properties —Hazardous Chemicals, Flammable Liquids; Flash Point Tests.

Aviation Gasoline

Standard Oil Company of New Jersey, Room 1610, 26 Broadway, New York 4, New York. Free.

In the opinion of many military men, the excellent quality and superior power of the aviation gasoline which has been supplied to our Army and Navy air arms has been one of the most important factors in the highly favorable box score which American flyers have been able to make against both the Nazis and the Japanese. Aviation gasoline requires special care in handling. It can be a hazard from the point of view of fire and explosion, and it can lose some of its own good qualities by careless handling.

Realizing the importance to military aviation, as well as to civil flying now and in the days to come, of safe and efficient handling of this super fuel, the marketers of Esso Aviation Products, who have invested millions of dollars in research, development and equipment to produce such a gasoline, have issued a booklet on its handling and storage. It points out that aviation gasoline does not serve its purpose until it enters the

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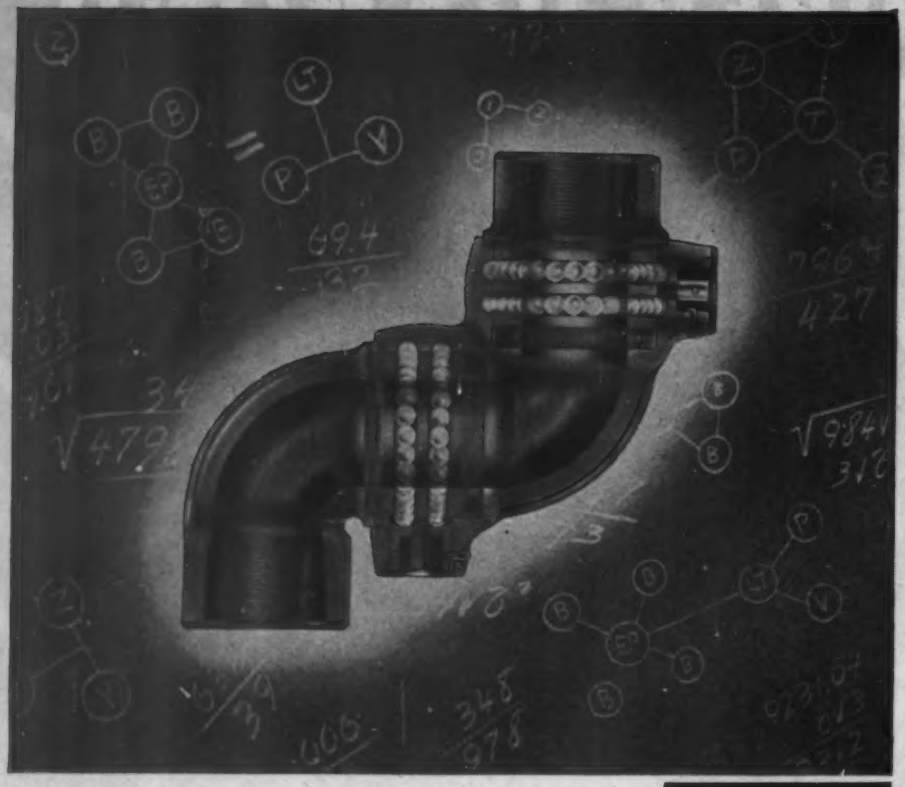

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tanks of an airplane. In the meantime it has to be handled and transported through many steps from refinery to flying field. The men who are engaged in this work, it declares, are charged with a serious responsibility.

The booklet, which is called *Aviation Gasoline,* describes, in plain and almost entirely non-technical language, both the nature of the aviation grades of gasoline, which range from 62 to more than a 100 octane rating and the methods by which they can be safely moved and stored. All of the grades currently available, it notes, except Grade 62, contain tetraethyl lead.

Methods of safely unloading and loading tank cars, tank wagons, marine tankers, drums and cans, are fully described. The handling of aviation gasoline and its storage at airports, which, it is believed, will become an increasingly important problem with the expansion of commercial and private flying after the war, is also outlined.

The booklet may be obtained from any of the Marketers of Esso Aviation Products in twenty-five states, including the Colonial Beacon Oil Company, Humble Oil & Refining Company, Standard Oil Company (Kentucky), Standard Oil Company of New Jersey, Standard Oil Company of Pennsylvania, The Standard Oil Company (Ohio).

Seized Chemical Patents Abstracted and Indexed

Publication of a 388-page Supplement and a 360-page Master Index in the seized enemy chemical patent abstracting program has just been announced by Alien Property Custodian James E. Markham. This was undertaken by the Chicago section of the American Chemical Society and the Science-Technology group of the Special Libraries Association.

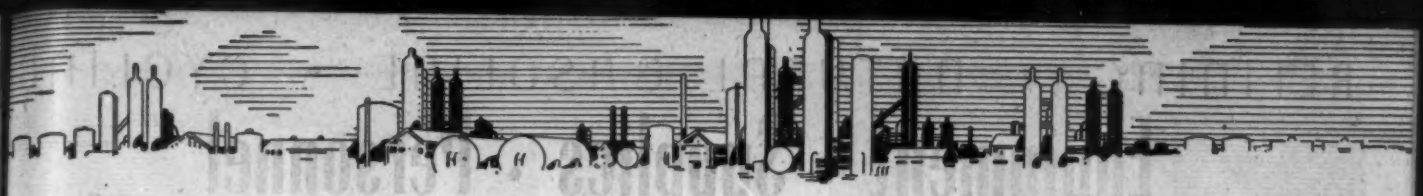
The publication provides access to 8000 seized chemical patents, the bulk of which were issued to Germans.

The Master Index contains more than 32,000 references and cross-references as well as a numerical list of all abstracted chemical patents and patent applications. The Supplement consists of 1700 classified abstracts of chemical patents vested since the earlier abstracts were prepared.

A somewhat similar program is being followed with the 37,000 seized mechanical, electrical and other non-chemical patents. Here the summary or abstract for each patent consists of a reproduction of one claim, one figure of the drawing, the patent number, the title of the invention, and the inventor's name and address. Classification is according to Patent Office classes and sub-classes. The material is indexed to facilitate search for significant material. Abstracts of patents on chemical machinery and apparatus are included in this publication. Two of the four volumes have been published and include Patent Office classes 1 to 150. The remaining two volumes are expected to be available during the next two months.

Complete sets of chemical and non-chemical abstracts may be purchased for $25 each from the Office of Alien Property Custodian, Chicago 3, Illinois. That office will also supply prices of separate sections or classes of these abstracts.

Over 8300 patents and patent applications have been licensed by the custodian to more than 600 American companies and individuals.



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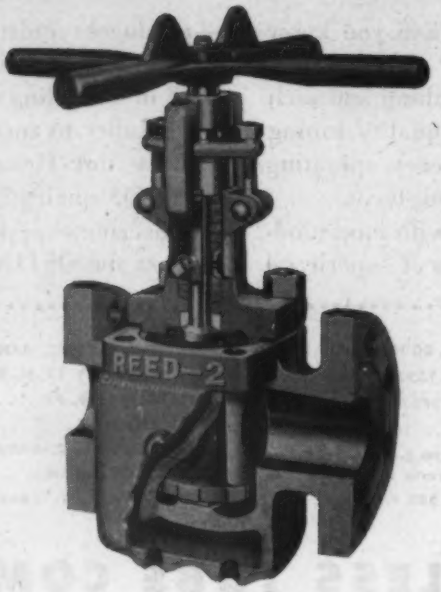
Reed Roller Bit Company, Box 2119, Houston 1, has developed a steel valve with a jacketing design which facilitates its operation at elevated temperatures. Temperature changes do not affect action of the valve discs, which are accurately guided by the disc holder, and yet are free to float with respect to the holder and the body seat. The valve does not require lubrication.

Reed Jacketed Steel Valves are interchangeable with wedge gate standard steel valves, and are supplied with A. S. A. standard for O. S. and Y. wedge gate valves.



Reed Jacketed Steel Valve

Dual-Fuel Engine
WORTHINGTON PUMP AND MACHINERY CORPORATION

Worthington Pump and Machinery Corporation, Harrison, New Jersey, announces that an engine capable of instantaneous conversion from oil to gas fuel without change in load or speed has gone into production at its Buffalo Works. Conversion from one fuel to the other or adjustment of a combination of both is accomplished by one revolution of a single control wheel.

Worthington Dual-Fuel Contol

Tests and public demonstrations, it was said, prove the new product highly successful; the first installation is operating in a large municipal plant.

The engine is able to burn either gas or oil or both together. Regardless of the fuel being used, the engine operates on the highly efficient diesel cycle, thus realizing fuel economies of the Diesel. It does not require a high-pressure fuel-gas supply, a pressure of two inches of water being used.

When operating as a gas engine, pilot oil ignition is used, eliminating electric ignition. Pilot fuel can be used in amounts as low as 5 percent of the total full load Btu requirements of the engine.

Fuel consumption as a gas engine is appreciably less than that of a similar engine operating on the conventional spark-ignition Otto cycle.

This system is produced to cover the range of the company's Diesel sizes, and units retain the distinctive features of Worthington design and construction.

Pop Valve
FARRIS ENGINEERING COMPANY

Farris Engineering Company, 345 Commercial Avenue, Palisades Park, New Jersey, has announced development of a pop relief valve which has an exceptionally high coefficient of lift for the disc. This high lift is secured through design of the valve disc, by which the velocity of the fluid is entrapped and its kinetic force converted into additional lift for higher relief discharge.

Farris pop valve Type 1800, designed for pressures up to 300 pounds, is built with an adjustable single blow-down ring which permits regulations of the amount of pressure to be relieved on individual operations. It also is available with a hand wheel for adjustments where changes of operating pressures are required, or with packed adjusting bolt under a protecting cap for gas service.

Alkali and Acid-Resistant Cement
THE U. S. STONEWARE COMPANY

The U. S. Stoneware Company, Akron, Ohio, is distributing its Bulletin R-5, "Duracite Alkali- and Acid-Resistant Cement." The product described is a furane-base resin cement, resistant to most inorganic acids, organic acids, alkalies of any degree of concentration, oils, and solvents.

Instruments
PRECISION SCIENTIFIC COMPANY

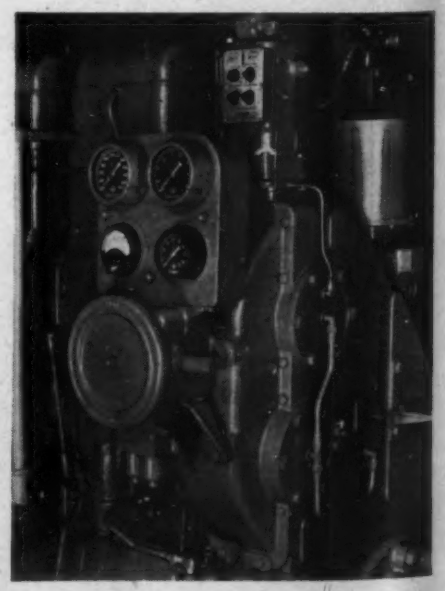
Precision Scientific Company, 1750 North Springfield Avenue, Chicago 47 has announced a new group of recording instruments, designated "Televac."

The type "MR" instrument with a range of 0-500 microns utilizes the new Televac No. 500 thermal gauge with specially treated elements. Features of latter include coated filaments to prevent "off calibration" periods due to water, oil vapor or other contaminating vapors, increased sensitivity gained through use of two filaments in both standard and variable tubes of the vacuum gauge, all gauges are interchangeable without recalibration, and the user is assured of duplicate readings in terms of absolute pressure in microns. The gauge is supplied with a special Leeds and Northrup "Micromax" strip chart recorder calibrated directly in microns.

The type "S" recorder for ultra vacuum contains two ranges—0-500 microns for pressures above 1 micron and utilizing the No. 500 thermal gauge in this range and an industrial type ionization gauge for the range 0 to 0.4 micron. Accurate readings may be obtained down to 10^{-4} mm Hg. (.001 micron). The type "S" instrument also features a safety circuit which makes it impossible to turn on the ionization gauge until a vacuum of 1 micron has been reached.

Gas-Oil Diesel Engine
THE COOPER-BESSEMER CORPORATION

The Cooper-Bessemer Corporation, Mount Vernon, Ohio, has announced production of an attachment which makes possible use of gas fuel in diesel engines without resort to high-pressure injection heretofore required for using this fuel. With this arrangement, the diesel engine can operate on any of the common fuel gases, in combination with oil, or on oil alone. Conversion



Control end of a Cooper-Bessemer Type JS-8 diesel, showing gas-oil operating mechanism.

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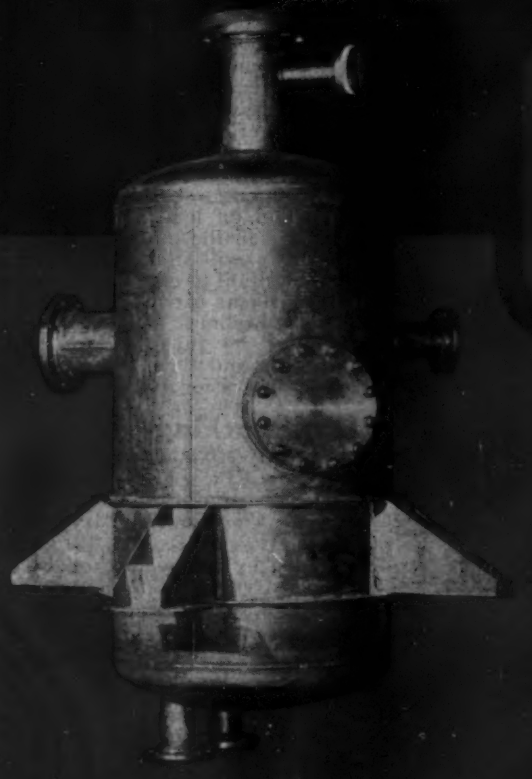
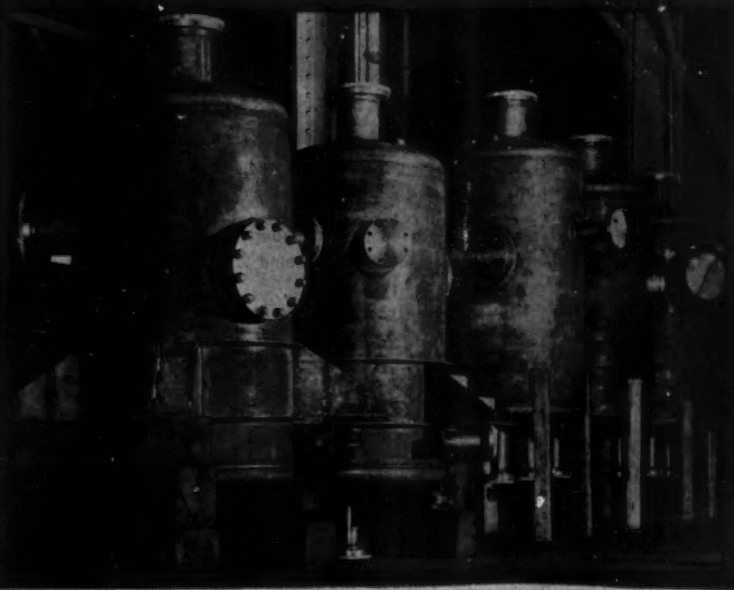


Vessels of stainless steel and other alloys are being fabricated by Beaird for service where high corrosion or extremely low temperatures are factors. These vessels are made to exacting specifications. Many of them are built to operate at sub-zero temperatures. Welds meet all the required Charpy impact tests at —150 degrees F.

Highest quality welding, rigid inspection and 26 years of experience in steel design and fabrication go into every Beaird vessel. ASME or API-ASME code construction.



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Complete resources permit Multi-Metal's up-to-the-minute fabricating shop to fit to your exact needs any Wire or Filter Cloth Unit, regardless of size, shape, design or metal. Multi-Metal skilfully constructs these units in conjunction with non-metallic materials too, making the simplest or most difficult assemblies.

To serve you better, Multi-Metal also fabricates assemblies not involving the use of Wire Cloth. Write for our catalog and send us your specifications.

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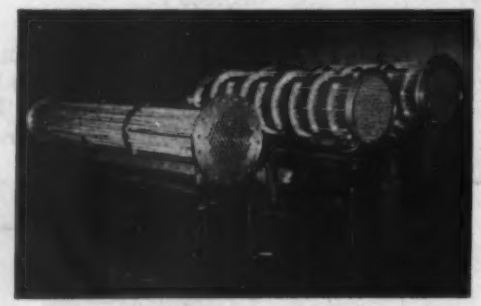
STAINLESS STEEL
Heat Transfer Equipment



Here we have illustrated a solid stainless steel (type 304) tube bundle from a steam heater for organic liquids. In the background are two of six tube bundles for organic vapor condensers. The tubes are solid nickel; tube sheets, baffles and tie rods are stainless steel (type 304).

In 1926 Downingtown built the first large stainless fabrication in the United States, with Dr. T. H. Nelson, consulting metallurgist, collaborating as he still does. Since that time many another piece of Downingtown built stainless chemical equipment has been installed.

On a recent job Downingtown built 48 heat exchangers, stainless Type 347 (18-8 Cb), bonnets heat treated and water quenched. On another, some 25 heat exchangers of stainless type 304 (18-8 S) were built.

Our heat exchanger bulletin illustrates many types of heat transfer equipment . . . send for your copy . . . on your letterhead, please.

Exchangers can be built to meet your performance specifications or if you wish we can build from your own drawings.

DOWNINGTOWN IRON WORKS
DOWNINGTOWN, PA.
HEAT EXCHANGERS

from liquid to gas fuel, or from gas to liquid, is as simple as the closing of one valve and the opening of another, with the engine operating continuously at full load. The control for this selection of fuel is attached to any of the company's models of diesel engines.

Ralph L. Boyer, chief engineer for the company, in discussing this development reviewed investigations back to 1927, and pointed out that an the assumption of pre-ignition no thought was given to the possibility of allowing the gas to go in with the intake air. The point that was not considered in this early work was that the efficiency of the diesel cycle makes the amount of gas required much less than with the Otto cycle, and the gas-air ratio at full load is still a very lean mixture, not easily ignited. It was found possible to admit the gas with the engine air intake without danger of premature ignition, and on very heavy overloads with natural gas, the mixture will not fire without a pilot oil flame.

"Assuming a diesel oil engine in operation and on load," he said, "if gas is admitted in the intake air the governor obviously will immediately reduce the amount of oil to compensate for the percentage being carried by the gas. It then merely becomes necessary to reduce the fuel oil injection to the desired minimum and then govern the percentage of gas according to load."

Flax Packing

GREENE, TWEED & COMPANY

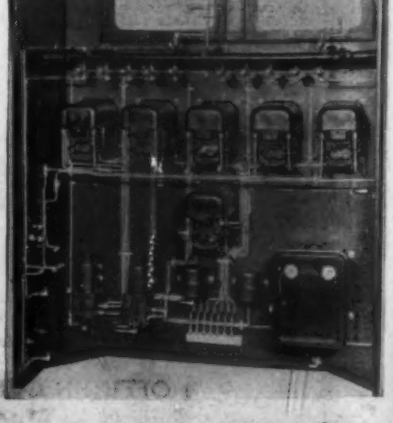
Greene, Tweed & Company, Bronx Boulevard at 238th Street, New York 66, has announced development of "Palmetto Square Flax Packing" which is made by a new method by which it claims a superior product is produced. In manufacture, each strand of flax roving is put through a machine which forces high-grade tallow under heat and pressure into each strand of flax. After this individual lubrication the strands are plaited to make finished packing. This treatment is said to defer hardening of the packing in service.

Boiler Control Panel

BAILEY METER COMPANY

Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio, is offering prefabricated boiler-control panels which include all necessary connecting piping and electrical wiring for operation of metering equipment and boiler-control systems. These panels are factory fabricated and tested.

Small units such as valves, relays, switches, signal lights, and the more



Section of prefabricated Bailey boiler panel

H_2O_2 $NH_2CONH_2 \cdot H_2O_2$

BECCO

$K_2S_2O_8$ $Na_4P_2O_7 \cdot 2H_2O_2$

$(NH_4)_2S_2O_8$ MgO_2

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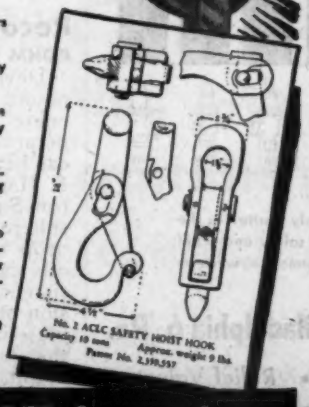
Thousands of ACLC Safety Hoist Hooks are "going into service"—carrying heavier loads with utmost safety—at lower cost in time and equipment. The basic reason? ACLC Safety Hoist Hooks are not merely built—but ENGINEERED—geared to today's crying need for more efficiency. Note these features!

- ★ Patented construction provides true alignment of load and hoist;
- ★ Eliminates load slippage and hook straightening;
- ★ Load is evenly distributed between safety shoulders and lip, giving extra load carrying capacity;
- ★ Even shearing of pin would fail to dislodge load; safety shoulders and lip lock would still hold!
- ★ Scientifically designed to prevent snagging — on hatches, cornices, etc., a common fault in ordinary hooks;
- ★ Each size of ACLC Safety Hook replaces 4 sizes of ordinary hooks. Net result — SAVINGS in EQUIPMENT INVENTORY.
- ★ The ACLC Safety Hook is a forged unit designed to take maximum load with minimum metal and averages approximately 1 lb. of metal actual weight per ton load lift as against standard open hooks of approximately 4 to 5 lbs. of metal per ton load lift.
- ★ Despite all these exclusive advantages, the ACLC Hoist Hook costs far less than ordinary hooks.



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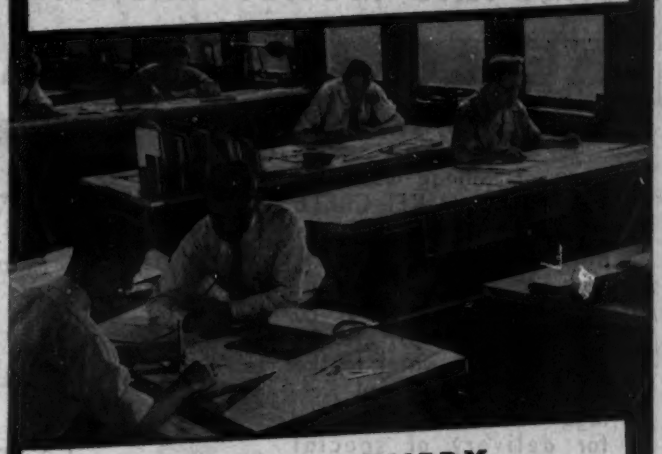

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In ADSCO'S large, modern plant with foundry and expert welding equipment, skilled workmen make a wide range of ADSCO Expansion Joints to meet exact code standards. They build them with bronze, semi-steel or steel bodies — for controlling the expansion of low or high pressure steam, hot water, gasoline, oil, air or other pipe lines.

Exclusive features of ADSCO Joints include the internal guide ring to prevent the slip from pulling out of the body — the external, two-piece removable guide — the Piston-Ring joint which can be unpacked and repacked under full operating pressure without interruption to service — the Duplex-Sleeve Joint, etc.

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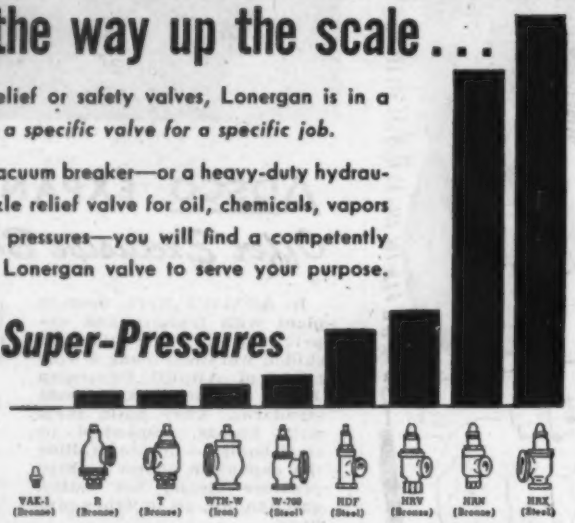

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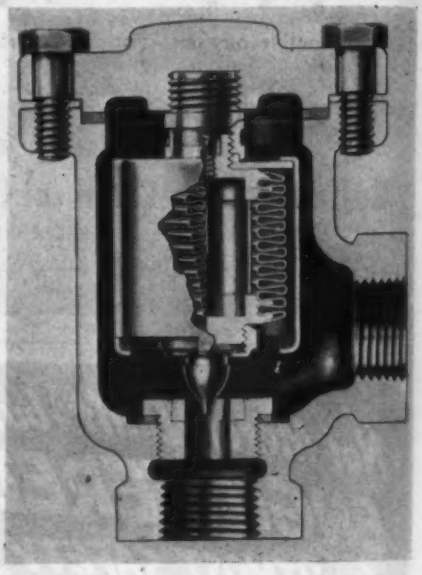
sturdy and light-weight instruments are mounted and ready for service. Heavy instruments or instruments having delicate mechanisms are shipped separately, but cutout spaces, drilling and all necessary connections are provided. Connecting piping and electrical wiring are brought to convenient terminals and tagged for guidance in connecting.

Steam Trap

SARCO COMPANY

Sarco Company, 475 Fifth Avenue, New York 17, has announced manufacture of bellows from heavy-wall bronze tubing, which has made possible the introduction of a new line of thermostatic steam traps, for pressures up to 225 pounds per square inch, using single, large diameter bellows, for inlet sizes ½-inch to 2 inches, inclusive, and with capacities double those of the company's No. 9 series. The new traps are available in two pressure ranges: No. 9-100 for pressures 0 to 100 pounds, and No. 9-225 for pressures 0 to 225 pounds.



Sarco Steam Trap

Tubing for the bellows which makes this new trap capable of withstanding the higher pressures, is drawn and helically corrugated in the company's own plant by methods of its own development. The heavy-wall bellows is screwed into the end enclosures and the joints are sealed by brazing, using the latest electronic-induction-heating equipment.

Recoil-Oil Additive

ROHM & HAAS COMPANY

Development of a new organic compound which prevents dangerous thickening of aviation oils at sub-zero temperatures or excessive thinning in tropical heat has been announced by Rohm & Haas Company, 222 West Washington Square, Philadelphia. In the stratosphere, where temperatures sometimes drop to —100° F., hydraulic and recoil oils can thicken to a solid tar-like consistency, jamming controls and transmission mechanisms. By combining this new material known as Acryloid HF with the selected oils a fluid condition is maintained in hydraulic systems in stratospheric and similar temperature extremes.

With aircraft which climb from tropical temperatures to the stratosphere in a few minutes the material functions as

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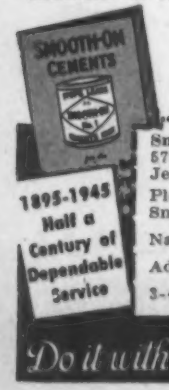

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the means of adjusting the oil to the rapid temperature changes. Rohm & Haas Company is issuing royalty-free licenses to oil companies enabling them to produce new types of hydraulic oils, hydraulic fluids and lubricating oils.

Aviation hydraulic oils are used in much the same way as the hydraulic fluids in automobile-brake systems. Power transmission through hydraulic oils raises and lowers landing gear, operates power turrets, and controls rudders, elevators, ailerons, and even propeller pitch. The recoil oil is the shock-absorbing medium in firing large and intermediate sized guns. If the recoil oil freezes, the plane might readily tear apart by the vibration of its own guns. Other important uses of the new "viscosity-index improver" are on ships in icy waters, on vehicles for arctic regions, and in other low-temperature operations. The new compound, a water-white acrylic polymer, has passed laboratory and field tests on stability under continued use and has proven successful in wide-spread military applications.

Acryloid HF marks another use for acrylics in aviation. Acrylics are the foundation of the Plexiglas transparent plastic used for bomber noses, gun blisters and other plane enclosures. Other acrylic compounds are used to dress shearlings for aviators' warm clothing and to treat parachute fabrics.

American Engineering Company Buys Cochrane and Faraday

American Engineering Company, 2440 Aramigo Avenue, Philadelphia, through stock purchase has acquired Cochrane Corporation, Philadelphia, and Faraday Electric Corporation, Adrian, Michigan. Both companies will operate as subsidiaries. Percy S. Lyon will continue as president and director of Cochrane Corporation, and will become a director of American Engineering Company. E. I. Kleinman, J. M. Doroshaw, J. S. Ackerman, Allison L. Bayles and Thurlow E. McBride, officials of American Engineering Company, have been elected directors of Cochrane Corporation.

American Engineering Company manufacturers power-plant items and marine equipment, and acquisition of Cochrane Corporation will augment and diversify its line of products in that field. Faraday Electric Corporation manufactures electric signalling devices and specialized household appliances. American Engineering Company in its strengthened position, it was said, will perticipate in more diversified engineering, research and manufacturing activities than heretofore.

R. L. Heath Now With Climax Molybdenum Company

R. L. Heath recently has joined Climax Molybdenum Company as a metallurgical engineer, and for the present will have headquarters at St. Louis. Before coming to this connection he was chief metallurgist of the Allison Division of General Motors Corporation, at Indianapolis, Indiana. While there he served on several SAE committees dealing with aircraft engine materials and packag-

R. L. Heath

Cleaning Absorption Towers and Stills!

Equipment downtime is nonproductive time. So when you have to remove sludge and carbonized oil deposits from trays, bubble caps and screens, keep equipment downtime at a minimum by using specialized Oakite cleaning materials and performance-proved Oakite methods.

Circulating hot solution of recommended Oakite material through equipment and then rinsing helps loosen and remove most accumulations that impair operating efficiency of towers and stills. The job is done "in place" . . . no dismantling required . . . units get back into service faster.

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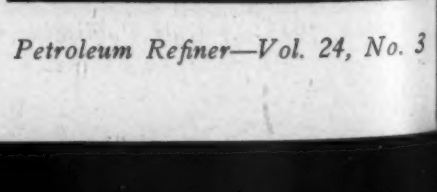

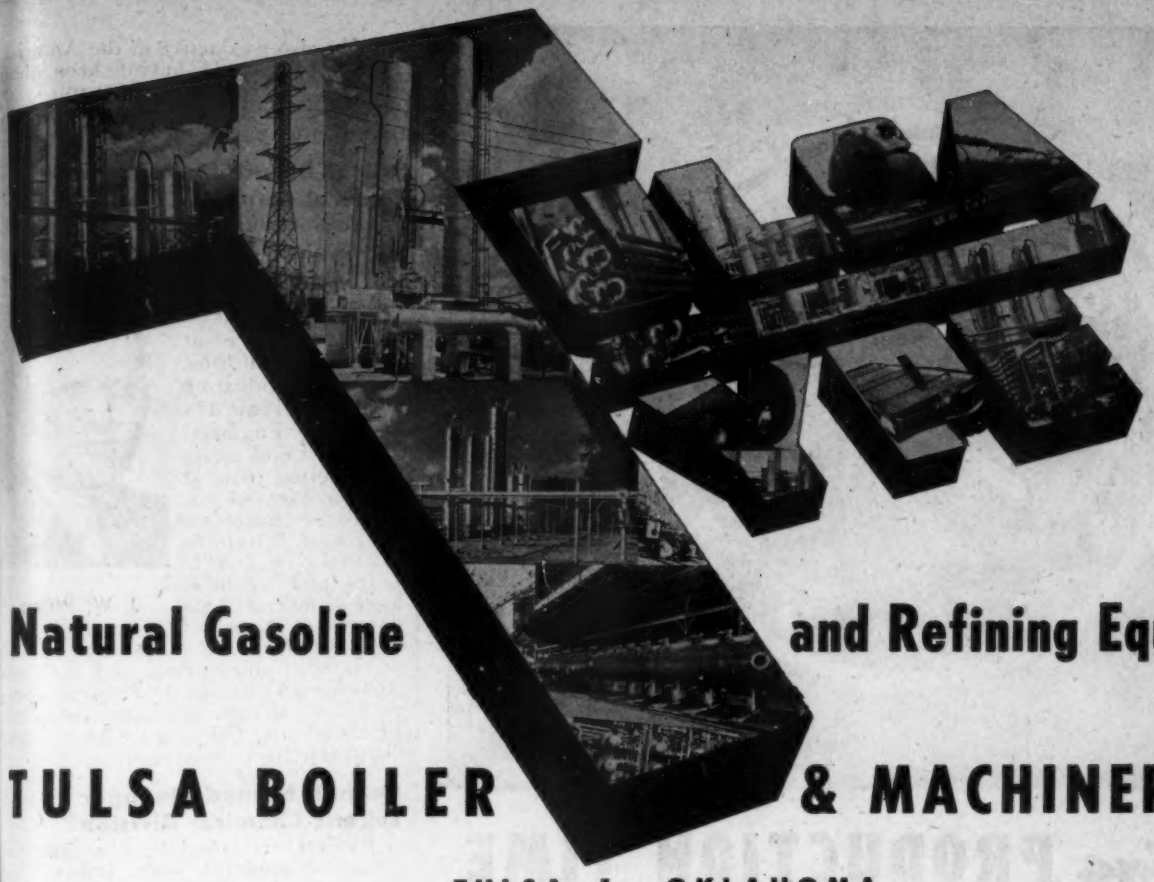

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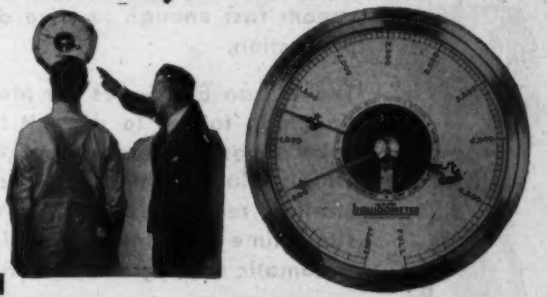

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ing. He also was active in the American Society for Metals, having been chairman of the Indianapolis chapter, and chairman of the constitution and by-laws committee in 1940-41.

Wilson Branch Manager for General Controls Company

Announcement has been made by General Controls Company of appointment of Joseph W. Wilson as manager of the company's branch office at Glendale, California. After graduating from Holland's Domestic Engineering and Combustion Engineering School, Wilson served as heating engineer for Holland Furnace Company for 15 years and as manager of several of the company's branches. He also for a time was sales engineer and later production manager for Kinney Aluminum Company. In his new position he will serve users of automatic controls in Southern California, Arizona and Southern New Mexico.

J. W. Wilson

Gosnell Named Manager Lukens Chemical Division

Everett C. Gosnell, who has been chemical engineer with Lukens Steel Company since 1937, has been appointed manager of the chemical division of that company and its subsidiaries, By-Products Steel Corporation and Lukenweld, Inc.

Gosnell received his bachelor's degree in chemistry from Rose Polytechnic Institute in 1925, and master degree in chemistry and metallurgy from Indiana University in 1927. Before joining Lukens Steel Company in 1937 he was chemist with Indiana Coke and Gas Company, chemical engineer with Koppers Company, and chemical engineer with the technical service division of The International Nickel Company.

E. C. Gosnell

Homestead Valve Company Making Cleaning Compound

Homestead Valve Manufacturing Company has started operating a cleaning-compound manufacturing plant at Edgeworth, across the Ohio River from the company's main plant at Coraopolis, Pennsylvania. The new plant will manufacture compounds for steam-spray machines for cleaning machinery and equipment.

Pittsburgh Steel Company Makes Sales Force Changes

A. S. Vandervoort, Jr., has been made sales manager, Mid-Continent district, for Pittsburgh Steel Company, with headquarters at Houston. He will direct sales on all products of the company in the west central states and Gulf Coast area. Vandervoort was district sales manager at Houston before entering the Army in 1942.

S. E. Elder, formerly district sales

THREE HUNDRED and sixteen Anaconda Super Nickel Tubes, ¾" O.D. by 18' long are handling 7250 barrels of crude per day in this hot naphtha vapor-to-crude oil exchanger at the Frontier Fuel Oil Corporation, Buffalo, N. Y. This exchanger is 20 ft., 3¼ inches overall with maximum flange diameter of 30½ inches.

Original design called for hot gasoline vapor at 275° F., but has been altered to use hot naphtha vapor at 400° F. Crude capacity of original design was 3500 barrels per day; has been increased to 7250 barrels per day.

This extra performance potential in Anaconda Copper and Copper alloy materials has been of inestimable value in meeting wartime demands and suggests your investigation of Anaconda Copper Alloy Tubes when you have a heat exchanger problem. For detailed information on alloys suitable for heat transfer or condenser equipment, write for Publication B-2. 45116

ANACONDA *Anaconda Copper & Copper Alloys*

THE AMERICAN BRASS COMPANY—General Offices: Waterbury 88, Connecticut

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KEEP FAITH WITH YOUR FIGHTERS AND YOURSELF! . . . BUY WAR BONDS FOR KEEPS

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SUPERIORITY

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BETTER STUFFING BOX DESIGN

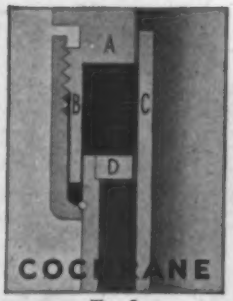

Fig. 1

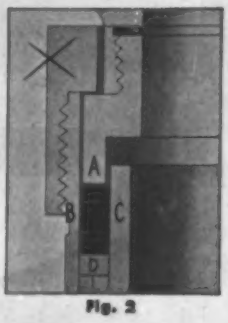

Fig. 2

Above are shown two rotameter stuffing boxes. As the fitting is screwed tight on both, pressure is exerted at A. In both, this packing is solidly backed at D, so pressure is even on areas B and C, which are, in effect, long cylindrical seals. In both, leakage is safeguarded along C, but in the ordinary rotameter (Fig. 2), when fluid gets past A, it is bound to leak because B is in no way effective. Now examine Cochrane's leakproof construction (Fig. 1). It cannot leak, because fluid getting past A would have to traverse entire surface of sealing face B to get out. Cochrane's is a *real* stuffing box.

OTHER EXCLUSIVE FEATURES:

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2. GUIDE ROD CENTERED IN TUBE
3. WHITE-BACKED TUBE
4. EASILY ADJUSTED STUFFING BOXES
5. INTERCHANGEABLE TUBES

Write for Publication R-100-A

COCHRANE CORP.
3107 N. 17th St.
PHILA. 32, PA.

COCHRANE-ROTAMETERS INC.
ROTAMETERS

manager at Tulsa, has been made assistant sales manager, Mid-Continent district, and will continue headquarters at Tulsa.

Paul R. King, who was sales representative for the company at Houston when he entered the Army in 1942, has returned and now is sales representative at Tulsa.

George W. Novak has been named chief engineer, Mid-Continent district, and will maintain headquarters at Houston. He has been field engineer at Houston for a number of years, and was acting district sales manager there while Vandervoort was on military leave.

Markl Chief Research Engineer for Tube Turns

Arthur R. C. Markl has been appointed to the post of chief research engineer for Tube Turns, Incorporated, Louisville, Kentucky. Markl is a graduate of the Technical Institute of Munich, and is a member of the American Society of Civil Engineers. Before joining Tube turns, he was for 14 years with The M. W. Kellogg Company at New York, last in charge of development of equipment for petroleum refineries.

A. R. C. Markl

Cooper-Bessemer Appoints Myers to Capital Post

Walter F. Myers has been appointed to the staff of the Washington office of The Cooper-Bessemer Corporation, where he will serve as assistant to Charles G. Cooper, director of that office, in the handling and supervision of government contracts and sales and service in the South Atlantic States.

Myers has had 25 years of experience in the equipment and diesel engine field as sales engineer, construction engineer and consulting engineer, having served with Fairbanks Morse Company, Federal Power Commission and United States Maritime Commission.

W. F. Myers

Duraloy Elects New Board Following Stock Purchase

The Duraloy Company, Scottdale, Pennsylvania, has purchased the stock interest of United States Pipe & Foundry Company in The Duraloy Company. The new board of directors includes T. R. Hayward, Jr., president; W. F. Furman, vice president in charge of operations; H. T. Harrison, vice president in charge of sales; W. L. King and F. S. Wynans. J. J. Baum is plant superintendent.

Reading-Pratt & Cady Names Wagner to New York Position

William Wagner has been appointed New York district sales manager for Reading-Pratt & Cady Division of

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For Temperatures up to 1700° F.

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Name_____

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Occupation_____

Employed by_____ P-16

American Chain & Cable Company, with headquarters at 230 Park Avenue. He has been with the Reading-Pratt & Cady sales department for 25 years. He succeeds E. Coit Magens who has been New York district sales manager for the past 25 years and who is now manager of the valve division, American Chain & Cable Company export department.

Donald Price Appointed Oakite Technical Director

Dr. Donald Price has been appointed technical director of Oakite Products, Inc., in connection with the company's plans to broaden and expand its technical service facilities. He will direct the activities of the company's engineering and chemical staffs, including its research laboratory and technical service department.

Dr. Donald Price

Dr. Price formerly was associated with Interchemical Corporation and National Oil Products Company, and is known for his research work on wetting agents, synthetic detergents, water repellants and sulphonated oils. He is vice president of the American Institute of Chemists, councillor of the American Chemical Society, member of the executive committee of the American Branch of the Institute of Chemists, and active in various other professional societies.

Sommers Chief Engineer for The Mathieson Alkali Works

Howard A. Sommers has been made chief engineer for The Mathieson Alkali Works, and will have headquarters at New York. A graduate of Chase School of Applied Science, Sommers joined the Mathieson organization in 1925 as mechanical engineer at the Niagara Falls ammonia plant, and later was assistant plant superintendent there. Then followed positions as superintendent of the dry-ice and lime-recovery plants at Saltville, Virginia; assistant plant engineer at the Niagara Falls plant; project manager from New York headquarters of the company; manager of the magnesium plant at Lake Charles, Louisiana, and project engineer in the New York office. Among his contributions to the chemical field are improved high-pressure valve and compressor packings; general design for the liquid-air and synthetic-ammonia industries; design and construction of magnesium and dry-ice plants, and of special rail cars and smaller containers for shipping dry-ice. He is a member of the American Society of Refrigerating Engineers, Compressed Gas Manufacturers Association, and Manufacturing Chemists Association.

F. T. Bumbaugh Promoted By Carnegie-Illinois Steel

Frank T. Bumbaugh has been promoted to manager of sales of Alloy Division of Carnegie-Illinois Steel Corporation. He succeeds the late Frank L. Gibbons, whose assistant he had been for the last three years.

Bumbaugh received his degree as metallurgical engineer at Lehigh University in 1924, and joined Carnegie-

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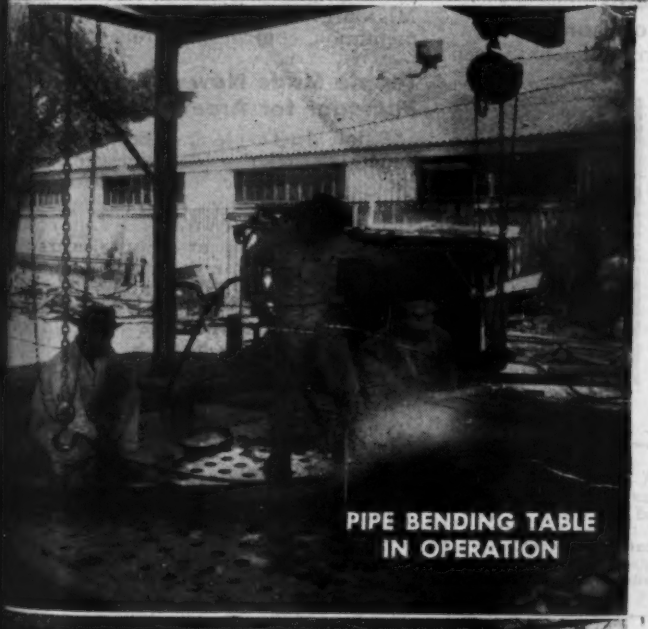
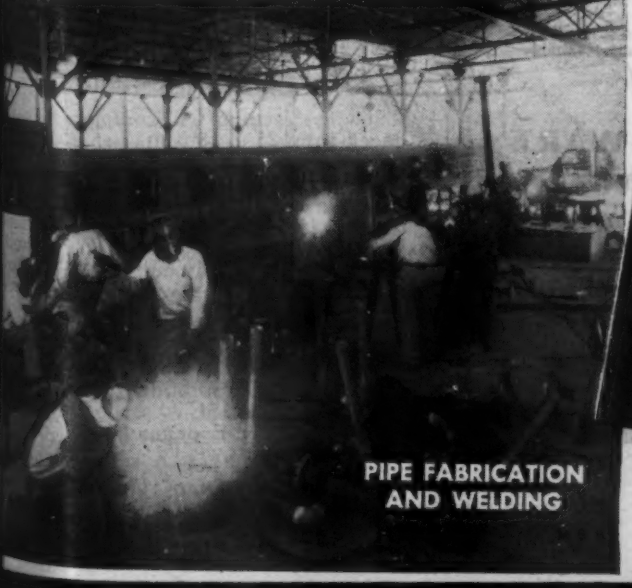


PIPE BENDING TABLE IN OPERATION



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Illinois Steel Corporation in 1926 at Duquesne Works. After service in Pittsburgh in the bar, semi-finished and alloy products division, he was transferred to Chicago where he served in the Alloy Division. He has served as chairman of the shell-steel committee and has held membership in the technical committee on government specifications and other technical committees. He has been a member of the iron and steel division of the standards committee of the Society of Automotive Engineers.

Pettus Heads American Brake Shoe Bearing Division

T. W. Pettus, who has been executive vice president of National Bearing Metals Corporation, until recently a subsidiary of American Brake Shoe Company, has been appointed president of National Bearing Division. The subsidiary was merged with the parent corporation late in 1944. Incorporated in 1927, National Bearing Metals Corporation was a merger of several non-ferrous foundries, and now operates seven plants. Other officers of the division include T. H. Wright, R. S. Herman, A. N. Dugan and W. E. Cartwright, vice presidents.

Elliott Company Appoints Assistant to President

G. L. Elliott, formerly general manager of Elliott Company's Springfield, Ohio, plant, has been appointed assistant in the tube-cleaner divisions, to Grant B. Shipley, president.

A. W. Chandler Joins Refinery Supply Company

A. W. Chandler recently has been added to the engineering staff of The Refinery Supply Company, at Tulsa, Oklahoma. He will be active in the department of gas engineering specialties which are manufactured by the company.

Chandler lately has been connected with Engineering Laboratories, Inc., in the capacity of chief mechanical engineer.

A. W. Chandler

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Chase Brass & Copper Company Makes Sales Personnel Changes

Chase Brass & Copper Company announced these changes in its sales force on February 1:

Marvin A. Joy, sales manager of the Midwestern division at Cleveland, was appointed assistant general sales manager of the Mill division, with headquarters at the company's principal office at Waterbury, Connecticutt.

Walter E. Evans, since 1940 sales promotion manager at Waterbury, has taken over the duties of sales manager at Cleveland.

John S. Coe, who has been assistant to Sherman H. Perry, general sales manager of the Mill division at Waterbury, has been appointed assistant to Wallace C. Husted, vice president in charge of Cleveland operations, at Cleveland.

New Company at Tulsa Offers Equipment Engineering Service

The Hayes-Condit Company has been organized at Tulsa to serve as manufacturers' representatives in the Mid-Continent and to provide engineering recommendations, sales and servicing for a number of equipment lines in the several branches of the petroleum industry. Headed by M. A. Hayes and D. J. Condit, the company will have headquarters at 624 South Cheyenne. Hayes for more than 20 years has been engaged in refinery engineering and construction. Condit, a chemical engineering graduate from University of Missouri, has had experience in instrumentation, control and process work.

Teeple Made New York Sales Manager for American Chain

Ralph J. Teeple has been appointed general district sales manager of the New York district of American Chain & Cable Company. He has been with Page Steel and Wire Division of the company for 23 years. Some years ago he had charge of the chain link fence sales department at Bridgeport. After serving in the Pittsburgh sales office, he was in charge of the Atlanta district, and for the past 5 years has been New York district sales manager for Page Steel and Wire Division.

W. H. Waldron Dead

William Hubeli Waldron, vice president and director of John Waldron Corporation, New Brunswick, New Jersey, died February 2. He was 80 years old and for 60 years had been active in the company which was organized by his grandfather in 1827. He graduated from Rutgers University in 1885, and was a member of the American Society of Mechanical Engineers.

Bead Catalyst Price Reduced

Socony-Vacuum Oil Company has reduced from 25 to 18 cents per pound the price of its bead catalyst. The beads were first used by General Petroleum Corporation at Torrance, California, less than a year ago. Increased use in thermofor catalytic cracking units throughout the country, it was said, has permitted production in quantity to justify the reduction.

Cochrane Gets Second Star

Cochrane Corporation, Philadelphia, has been awarded a second star for its Army-Navy E pennant.

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